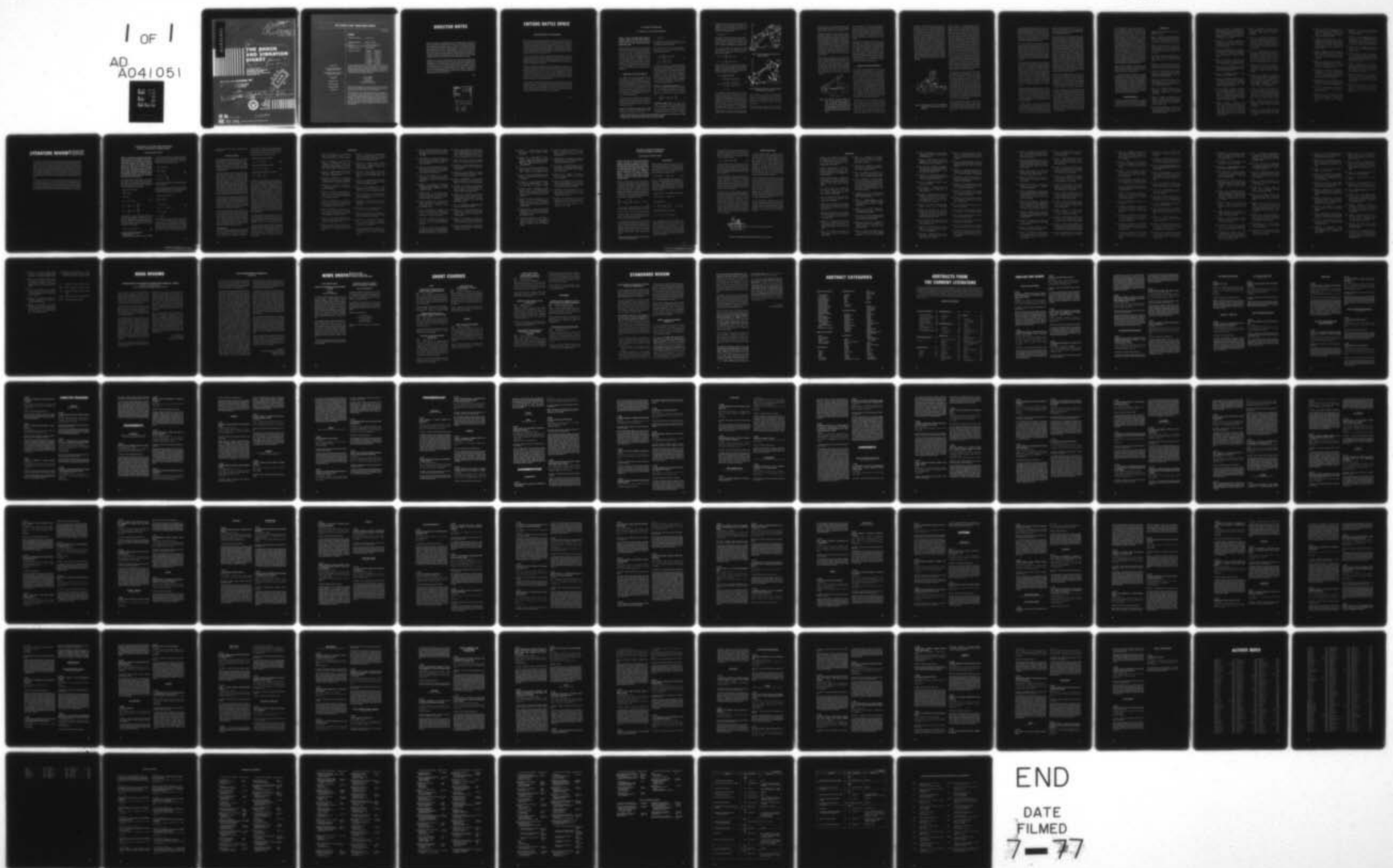
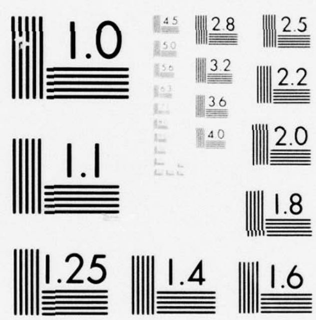
AD-A041 051 NAVAL RESEARCH LAB WASHINGTON D C SHOCK AND VIBRATIO--ETC F/G 5/2
THE SHOCK AND VIBRATION DIGEST. VOLUME 9. NUMBER 6. JUNE 1977.(U)
JUN 77 J NAGLE-ESHLEMAN

UNCLASSIFIED NL

1 OF 1
AD
A041051



END
DATE
FILMED
7-77



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

ADA041051

VOLUME 9, NO. 6

JUNE 1977

NW 12 94p.

6

THE SHOCK AND VIBRATION DIGEST

Volume 9. Number 6. June 1977,

A PUBLICATION OF
THE SHOCK AND VIBRATION INFORMATION CENTER
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C.

DDC
JUN 29 1977
C

FOR RECORD AND ANNOUNCEMENT ONLY

NOT TO BE REPRODUCED FOR SALE OR FREE DISTRIBUTION

may
be purchased from

Shock and Vibration Information Center
Naval Research Laboratory, Code 6020
Washington, D. C. 20390

10 Judith / Nagle-Eshleman

no copies furn by DDC/NTIS

OFFICE
OF THE
DIRECTOR
OF DEFENSE
RESEARCH
AND
ENGINEERING

AD No. 389004

DDC FILE COPY

Approved for public release; distribution unlimited.

THE SHOCK AND VIBRATION DIGEST

Volume 9 No. 6
June 1977

STAFF

EDITORIAL ADVISOR: Henry C. Pusey

TECHNICAL EDITOR: Ronald L. Eshleman

EDITOR: Judith Nagle-Eshleman

RESEARCH EDITOR: Milda Tamulionis

BOARD OF EDITORS:

R. Belsheim	W. D. Pilkey
R. L. Bort	A. Semmelink
J. D. C. Crisp	E. Sevin
C. L. Dym	J. G. Showalter
D. J. Johns	R. A. Skop
G. H. Klein	C. B. Smith
K. E. McKee	J. C. Snowdon
J. A. Macinante	R. H. Volin
C. T. Morrow	H. von Gierke
J. T. Oden	E. E. Ungar

A publication of

THE SHOCK AND VIBRATION INFORMATION CENTER

Code 8404 Naval Research Laboratory
Washington, D.C., 20375

Henry C. Pusey
Director

Rudolph H. Volin

J. Gordan Showalter

Barbara Szymanski

Carol Healey

The Shock and Vibration Digest is a monthly publication of the Shock and Vibration Information Center. The goal of the Digest is to provide efficient transfer of sound, shock, and vibration technology among researchers and practicing engineers. Subjective and objective analyses of the literature are provided along with news and editorial material. News items and articles to be considered for publication should be submitted to:

Dr. R. L. Eshleman
Vibration Institute
Suite 206
101 West 55th Street
Clarendon Hills, Illinois 60514

Copies of articles abstracted are not available from the Shock and Vibration Information Center (except for those generated by SVIC). Inquiries should be directed to library resources, authors, or the original publishers.

This periodical is for sale on subscription at an annual rate of $40.00. For foreign subscribers, there is an additional 25 percent charge for overseas delivery on both regular subscriptions and back issues. Subscriptions are only accepted for the calendar year, beginning with the January issue. Back issues are available by volume (12 issues) for $15.00. Orders may be forwarded at any time, in any form, to SVIC, Code 8404, Naval Research Laboratory, Washington, D.C., 20375. Issuance of this periodical is approved in accordance with the Department of the Navy Publications and Printing Regulations, NAVEXOS P-35.

DIRECTOR NOTES

Recently, I have given some thought to the cost of managing shock and vibration technical information as related to other cost factors in the research, development, test, evaluation and procurement process. In doing this I made several assumptions each of which tend to project a conservative picture. First, I looked only at the defense budget which currently exceeds 100 billion dollars, about one fourth of which is for procurement. Next I assumed that only one tenth of one percent of this money is spent in generating shock and vibration information required for the successful development and deployment of all defense systems. The SVIC budget represents about one half of one percent of this 100 million dollar figure.

Certainly such a comparison is hypothetical, but it is valid enough to allow certain observations. In terms of dollars, we place a high value on the development and documentation of new technology but give little emphasis to the treatment of this information once we have it. Systematic evaluation and dissemination of information is a necessary part of technological progress. Even at several times the present cost, a service performing this function would still be a bargain. Furthermore, if the function is performed effectively, the money saved in avoiding duplication of effort alone would more than pay for it.

H.C.P.

ACCESSION for
NTIS White Section ☑
DDC Buff Section ☐
UNANNOUNCED ☐
JUSTIFICATION........
BY........
DISTRIBUTION/AVAILABILITY CODES
Dist. AVAIL. and/or SPECIAL
A 21

EDITORS RATTLE SPACE

POSTER SESSIONS: GOOD OR BAD?

Some professional societies are attempting to cope with the proliferation of technical papers by scheduling "poster sessions." During a poster session, authors who have written up work about specific topics are assigned booths. Each author has a display board and table and presents his talk to anyone who wants to hear it. The data and explanatory material are presented in a poster format; some authors also show slides or give demonstrations. Whether or not such sessions are effective is open to debate. (Whether or not the increased volume represents good technical material was examined in an earlier editorial.)

Those in favor of poster sessions claim that they allow participants to communicate directly with authors, thereby creating an atmosphere that stimulates the exchange of ideas. In my opinion such exchange is an important part of the normal technical meeting process: after an author has presented his paper, those who are genuinely interested discuss it with him.

Those who oppose poster sessions claim that the bazaar-like atmosphere is not conducive to creative or meaningful discussions. Furthermore, all the authors are displaying their material at the same time. It is difficult enough for participants to see everything they want to see, but it is almost impossible for the authors to interact. I believe that this lack of interaction is a big disadvantage of poster sessions. Everyone benefits from question and answer periods during technical meetings, not just a few people who happen to be at the right booth at the right time, so to speak, during a lively exchange of ideas.

In my opinion the poster session does not allow sufficient exposure of work in progress or exchange of ideas. Poster sessions are incomplete presentations of what might be excellent work. The presentation of a paper by an author during a typical technical session is a learning experience for everyone. It seems to me that the answer to the proliferation problem is to use only the best technical papers instead of trying to present work in a limited way -- by poster sessions.

R.L.E.

BALANCING OF LINKAGES

R.S. Berkof*, G.G. Lowen**, and F.R. Tepper***

Abstract - Interest in high-speed machine design has stimulated research and developmental efforts in balancing during the past few years. This paper reviews some of the recent literature dealing with balancing of linkages.

Shaking forces and shaking moments generated by an unbalanced mechanism cause problems that affect the life of a machine. The higher the speed and/or the greater the mass in the linkage, the greater the vibrations, noise, wear, and fatigue. Methods for full and partial force balancing of linkages have received much attention recently. This review is concerned with publications since 1973, especially those pertaining to the balancing of general planar and spatial mechanisms. The publications cited deal with complete or partial balancing of forces and/or moments. A more comprehensive survey was published in 1968 [23].

COMPLETE BALANCING TECHNIQUES

Two general rules have been established for full force balancing of planar linkages [42]. The first states that a planar mechanism without axisymmetric link groupings can always be fully force balanced by internal mass redistribution if, and only if, for each link there is a path to the ground by way of revolutes only. The second rule is a generalization of the method of linearly independent vectors: the full force balance of a balanceable planar n-link mechanism is possible with an "apparent" minimum number of n/2 counterweights [4].

Generalization of the method of linearly independent vectors involves three steps deriving an equation for the position of the linkage center of the mass, eliminating the time-dependent coefficients, and equating the coefficients to zero.

Equation for position of linkage center of mass. Equation (1) is a vectorial expression that describes the trajectory of the linkage center of mass.

$$\bar{r} = \frac{1}{M} \sum_j m_j \bar{r}_j \tag{1}$$

The quantity m_j is the mass of moving link j; $\bar{r}_j$ is the position of the center of mass of link j; and M is the total mass of the moving links.

The positions $\bar{r}_j$ are written in terms of link dimensions and unit vectors $e^{i\phi_j}$, which describe the angular position of each link.

$$\bar{r} = \frac{1}{M} \left\{ \sum_j \left[(A_j + \sum_k B_{jk}) e^{i\phi_j} + \sum_p T_{pj} e^{i\phi_j} \right] + \bar{C} \right\} \tag{2}$$

In equation (2) A_j are time-invariant mass-distance products that relate individual link centers of mass with their body-fixed origins; B_{jk} are time-invariant mass-distance products that relate body-fixed pivot-to-pivot dimensions for links with more than two connections to other links; T_{pj} are mass-distance products that relate time-dependent link-to-link dimensions (e.g., sliding joints); and $\bar{C}$ is a constant. Full force balance is possible if the time-dependent terms T_{pj} are not present (e.g., linkages with revolutes only) or can be eliminated.

Elimination of time-dependent coefficients. If mechanism loop equations are possible, expressions for T_{pj} can be obtained and substituted into equation (2). If all time-dependent terms are eliminated, equation (2) reduces to the form shown in equation (3).

$$\bar{r} = \frac{1}{M} \left[\sum_j (A_j + \sum_k B_{jk}) e^{i\phi_j} + \bar{C} \right] \tag{3}$$

Coefficients equated to zero. The position of the center of mass is made stationary with respect to time to fully force-balance the linkage. Each coefficient of $e^{i\phi_j}$ is set equal to zero because each is linearly independent. Conditions for the minimum number of counterweights needed to balance the linkage are

*Manager, Advanced Technology, Gulf & Western Advanced Development and Engineering Center, Swarthmore, PA 19081
**Professor, The City College of the City University of New York, New York, NY 10031
***Physical Scientist, Fuze Development Branch, Picatinny Arsenal, Dover, NJ 07801

obtained by solving loop equations of contours with revolutes only for certain unit vectors $e^{i\phi_j}$. The substitution of these expressions into equation (3) reduces the number of coefficient terms. Each coefficient term is then equated to zero.

$$A_j + \sum_k B_{jk} = 0 \tag{4}$$

The solution of this set of equations yields relationships between link masses and link geometries that must be fulfilled to obtain force balance. Such relationships can be satisfied by either redesigning links or adding counterweights to selected links.

For a four-bar linkage with arbitrary link mass distributions (see Fig. 1), for example, the linkage will be fully force balanced if the conditions in equation (5) are satisfied.

$$\begin{aligned} m_1 r_1 &= m_2 r_2' \frac{a_1}{a_2} \text{ and } \theta_1 = \theta_2', \\ m_3 r_3 &= m_2 r_2 \frac{a_3}{a_2} \text{ and } \theta_3 = \theta_2 + \pi. \end{aligned} \tag{5}$$

These conditions can be used to design a balanced linkage. If links of an unbalanced four-bar linkage are given and counterweights are to be added to force balance, as in Figure 2, the conditions in equation (6) must be satisfied by the counterweights.

$$\begin{aligned} m_i^* r_i^* &= \sqrt{(m_i r_i)^2 + (m_i^0 r_i^0)^2} \\ &\quad \sqrt{-2\, m_i m_i^0 r_i r_i^0 \cos(\theta_i - \theta_i^0)}, \\ \tan \theta_i^* &= \frac{m_i r_i \sin \theta_i - m_i^0 r_i^0 \sin \theta_i^0}{m_i r_i \cos\theta_i - m_i^0 r_i^0 \cos \theta_i^0} \\ &(i = 1, 3) \end{aligned} \tag{6}$$

The influence of full force balancing by this method on the resulting forces and moments of four-bar linkages has been studied for 39 families of such mechanisms with standard inline configurations [25]. It was found -- with some exceptions and depending somewhat on the location of the center of mass of the inline coupler -- that the bearing forces, the input moment, and the shaking moment are about 50 percent greater than those of the unbalanced mechanisms*. This increase is true for both rms and maximum values. The maximum values were generally not more than three times the associated rms values. The counterweights required for full force balancing, if made of the same material as the links and kept to a reasonable thickness, occasionally became bulky.

When space limitations prevent the full force balance of a given four-bar linkage, the addition of a link

*When the coupler link of the four-bar linkage has a general mass distribution, this increase can be considerably larger.

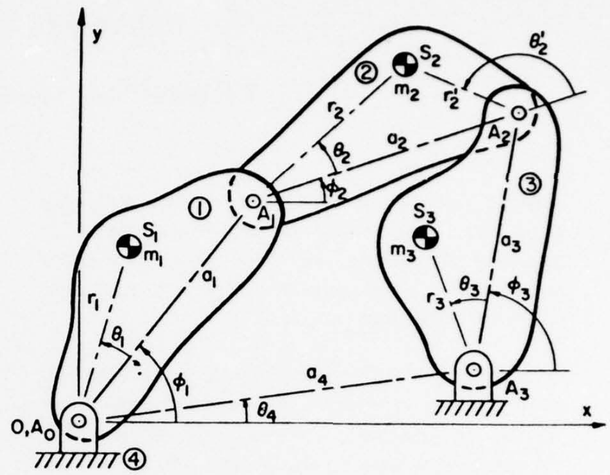


Figure 1. Four-bar Linkage with Arbitrary Link Mass Distributions

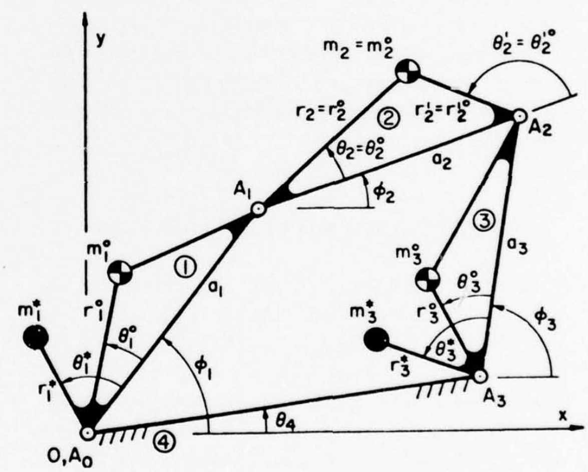


Figure 2. Balancing of Prescribed Four-bar Linkage of Counterweights to Links 1 and 3

dyad may supply a more advantageously shaped and still balanceable mechanism [11]. A planar tenbar linkage has been used in the textile industry [35].

The balancing conditions of the method of linearly independent vectors for general four-bar linkages have been determined by introducing what might be termed imaginary principal vectors, in addition to the real ones [33]. The magnitude of these vectors must be proportional to the pivot-to-pivot dimensions of their associated links if the center of mass of the mechanism is to remain stationary at all times. The first harmonic of the shaking moment can be eliminated by attaching the required input link counterweight, not to the input shaft, but to a suitably offset one that rotates at the same velocity as the input shaft.

When an inline four-bar linkage is fully force balanced, the resulting shaking couple can also be completely eliminated, regardless of input speed variations, when the coupler link represents a physical pendulum and when geared inertia couterweights are introduced [4, 5]. These counter-rotating disks must be geared to both the input and output shafts with a gear ratio of minus one. Such a fully force and moment balanced four-bar linkage is illustrated in Figure 3.

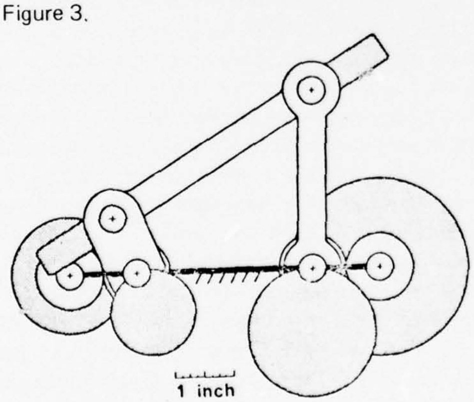


Figure 3. **Fully Balanced Four-Bar Linkage. Elements of mass redistribution include circular force-balance counterweights on crank and rocker links, rotary inertia counterweights geared to crank and rocker links, and masses added to the coupler link such that it has the properties of a physical pendulum.**

The techniques of full force and moment balancing have been applied to a slider-crank mechanism. Linkages with and without a slider offset were considered. Linearly independent vector balancing techniques for general four-bar linkages can start with a two-mass replacement of the coupler link at its pivots if these masses are represented by complex numbers.

Appropriate counterweights can be used for full force balance of a machine in which reciprocating motion is furnished by straight line motion associated with a point on the periphery of the planet wheel of a Cardan gear mechanism or its kinematic equivalent. Shaking moment balance is automatic at constant input speed, and an appropriate mass distribution assures shaking moment balance at variable input speeds. Automatic balance has been used in a theoretical analysis of two kinematically equivalent machines [17-19]; one is an eccentric mechanism. Experimental results were also presented.

PARTIAL BALANCING TECHNIQUES

The increase in bearing forces due to full force balancing is often undesirable; in such cases partial force balance is used. One method involves optimizing the rms shaking force of a general four-bar linkage with a constant input speed [41]. A Lagrange multiplier formulation is used to limit the increase in rms ground bearing forces to values between those of the unbalanced mechanism and the fully balanced mechanism. This optimization has been successful with both a single counterweight attached to the output link and two counterweights on the input and output links. The two counterweight technique can produce considerably lower rms bearing forces for comparable rms shaking forces than the single counterweight. Practical counterweight dimensions were obtainable even though the counterweights were made of the same material as the links.

The shaking moment of a fully force balanced mechanism invariant with respect to reference point has been compared to that of an unbalanced or partially balanced mechanism by the theory of isomomental ellipses [39, 40]. The rms shaking moment of an unbalanced planar mechanism is constant at all points along certain concentric ellipses in the mechanism plane. Furthermore, the rms shaking moment

decreases for reference points on ellipses of decreasing size; the center of the isomomental ellipses represents that point in the mechanism plane at which the rms shaking moment is a minimum. The theory of isomomental ellipses has been extended to the evaluation of the shaking moment of spatial mechanisms [8]. Partial force balancing of four-bar linkages with a single counterweight attached to the output link has been studied [24]. The rms shaking force remained constant so long as the mass-distance products associated with the center of mass of the link lay on certain circles. The radii of these "equipollent" circles increased with increasing rms shaking force. The counterweight configuration associated with the minimum rms shaking force was easily determined by letting the radius be zero. Flexibility in counterweight design is possible because many counterweight radii and angles will produce the same rms shaking force if it is allowed to be larger than the minimum attainable.

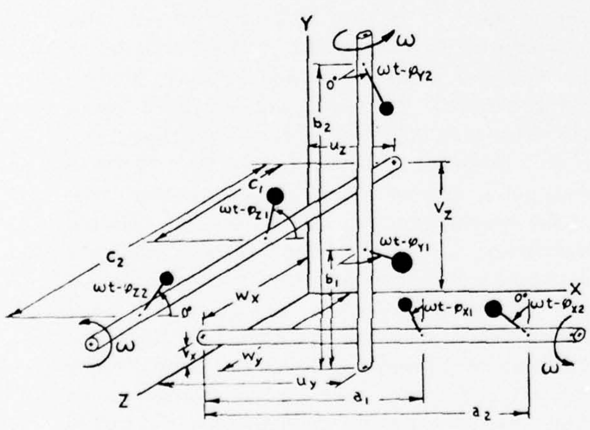


Figure 4. Configuration of Shafts and Balancing Weights Showing Positive Dimensions and Rotations

The first harmonics of the shaking force and the shaking moment of a three-dimensional machine aggregate can be eliminated [38] by attaching two masses to each of three mutually perpendicular shafts rotating at the speed of the harmonics (see Fig. 4). The harmonics cannot always be completely eliminated, however, because the required shafts might not be available. In such cases, partial balancing that minimizes displacement of certain points on a machine is used. Nonlinear programming techniques have been used to minimize certain movements in a constant input speed general four-bar linkage. Point mass counterweights attached to the input and output links were used. (The counterweight moments of inertia can be neglected insofar as any effect on the shaking force, but they do affect the shaking moment, the input moment, and the various bearing forces.) In one case the shaking force was minimized and the magnitude of the shaking moment was limited. This optimization was repeated with an additional constraint on the maximum value of the largest bearing force, and all solutions were summarized in trade-off charts. Constrained optimization problems were converted to unconstrained ones with the exterior penalty function approach. The optima were determined with a variable metric procedure.

This optimization procedure has been applied to six-bar linkages [30]. The shaking force, the shaking moment, the input torque fluctuation, and a bearing force were minimized by one and two point masses of prescribed magnitude. Either two or three balancing masses were used in a trade-off between maximum shaking force and input torque fluctuation. For the two balancing mass case, the trade-off was accomplished both with and without an additional bearing force constraint. Maximum shaking force and shaking moment were reduced by 40 percent for a six-bar stone crusher mechanism, a composite objective function was used. The efficiency of nonlinear programming, for linkage balancing was demonstrated by duplicating the analytical full force balance results for four- and six-bar linkages.

Kinematic synthesis and the dynamic design of four-bar linkages have been combined in a unique study [9]. Nonlinear programming was successfully used to determine the linkage that satisfies kinematic objectives and also provides optimum dynamic characteristics.

A general mechanism analysis computer program for balancing linkages has been described [10]. The program MEDUSA was used with test masses for counterweights at three positions on both crank and rocker links of a four-bar linkage. Linear counterweight parameters were formulated for the joint force expressions so that the shaking force could be minimized with a quadratic objective function.

A computer program that can generate the various reactions of planar linkages and optimize them with nonlinear programming techniques has been described [32]. A weighted optimization of the shaking moment and the input torque of a six-bar linkage was used. According to theory, minimum inertia counterweights should be circular and tangent to the link pivots; theoretical results were confirmed by a search procedure during work related to balancing [34].

The vibration-free performance of a motorcycle engine has been studied [16]. No engineering details are given, but the description indicates that the engine has a chain-driven generalized Lanchester balancer. (See references 11, 18, 58, and 59 in Lowen and Berkof [23] on this device, which allows the elimination of both orthogonal components of a chosen shaking force harmonic.) Modified Lanchester balancers are still used with reciprocating engines; for example, to reduce both second order vertical shaking force and shaking moment effects [27]. The balancer was used in a four cylinder IC engine to demonstrate the effect on noise reduction.

An alternate balancing arrangement for two- or four-cylinder engines has been reported [1]. A device resembling an inverted scotch yoke mechanism was used to drive a counterweight opposite the piston assembly; most of the shaking force was balanced. A specific application of simple balancing to mine grate screens driven by slider-crank linkages has also been described [29].

A linkage in which a connecting rod is used and its motion measured from a point in the interior of the planet wheel has been described [20]. Two partial force and moment balancing techniques do not fully account for the moment of inertia of the connecting rod. A machine with an internal gear for producing cardanic motion was tested for vibration on a previously described platform [18]. The experimental amplitudes were small and compared reasonably well with those predicted by theory.

The partial balancing of the shaking force due to the reciprocating masses of a slider-crank mechanism has been studied [36]; the rotating masses were assumed to be balanced. A computer search established ratios of crank counterweight masses to reciprocating masses necesary to obtain the lowest maximum shaking forces for various crank-connecting rod length relationships. Mechanisms running at constant speed and free-running mechanisms were used. The initial velocity was known; the response in the absence of an input torque was determined by solving a differential equation. An experimental technique for determining the shaking force and the shaking moment of a single cylinder engine was developed [21, 22] because the actual mass distribution in the links was not known. During the experiment, the mechanism was run on a spring supported platform. The amplitudes of the first two harmonics of the shaking force and the shaking moment were determined by measuring linear and angular displacements of the platform.

There has been considerable interest in input torque smoothing (as computed at constant speed) for keeping input speed variations of the mechanism--when driven by a torque sensitive motor--within reasonable limits. It has been shown that Lagrange's equation can be used to obtain a simple expression for the input moment as a function of the time rate of change of the kinetic energy of a mechanism [6].

A draglink mechanism with a compensating mass on the coupler was studied with a technique developed by Hockey and Sherwood [28]. The fluctuations of input speed were compared to those obtained when the mechanism was used without the added coupler mass but had a flywheel. (The flywheel gave the same fluctuation.) The mechanism with the corrected coupler generally had smaller fluctuations in input speed than that with the flywheel. Theoretical predictions were low because the friction in the bearings had been ignored. The quantity of material added to the coupler was much smaller than that required for the flywheel.

The flywheel has been used to smooth out the power cycle. Oscillations in mechanisms have been minimized by tuning the flywheel; i.e., by optimizing the choice of flywheel inertia and connecting shaft stiffness [26]. The resisting moment -- including inertia, friction, and work -- was characterized by a fourier analysis. Springs have been used for energy storage and as exchange media. The spring balancing of a four-bar linkage has recently been examined [15]. This approach was developed to smooth the torque requirements of such devices as those in antenna drive systems. Springs or cam-driven masses have also been used to smooth input torque [13]. Spring parameters have been synthesized to generate a desired time response of the mechanism. The input angular velocity was smoothed by a least-square synthesis technique and applied to the slider-crank and four-bar linkages. The general approach and description of computer programs involved in force system synthesis has been published [7]; detailed least-square synthesis techniques have also been developed [13].

Spreitzer [37] has expanded on previous work (see [23]) related to the motion of the total center of mass of a linkage. This theory was used in a study of a five-bar linkage with two drive cranks.

In summary, the theory of the balancing of linkages for shaking force, shaking moment, input torque, bearing forces, or other internal loads has advanced in the past few year. The theory is being applied to machines and devices in order to optimize design and improve performance. In addition, the balancing of high speed machines has allowed increases in maximum speeds without introducing deleterious vibrations. Unfortunately, many of these practical applications are considered proprietary, and descriptions rarely appear in the published literature.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the invaluable contribution of Mr. S. Tricamo of the City College of the City University of New York, who assisted the authors in the review of nonlinear programming.

REFERENCES

1. "Balanced Crank Mechanism," Engineering, pp 898-899 (Nov 1975).

2. Bagci, C., "Shaking Force and Shaking Moment Balancing of the Plane Slider-Crank Mechanism," Proc., Fourth Appl. Mechanisms Conf., Oklahoma State Univ., Paper No. 25 (Nov 1975).

3. Benedict, C.E. and Tesar, D., "The Use of Influence Concepts in Treating the Dynamics of Machine Problems," Proc., Third Appl. Mechanisms Conf., Oklahoma State Univ., Paper No. 43 (Nov 1973).

4. Berkof, R.S., "Balancing Concepts and the Four-Bar Linkage," Proc., Third Appl. Mechanisms Conf., Oklahoma State Univ., Paper No. 9 (Nov 1973).

5. Berkof, R.S., "Complete Force and Moment Balancing of Inline Four-Bar Linkages," Mechanism Mach. Theory, 8 (3), pp 397-410 (1973).

6. Berkof, R.S., "On the Input Torque in Mechanisms," Proc., Fourth World Cong. Theory Mach. Mechanisms, Newcastle-upon-Tyne, G.B., Instn. Mech. Engrs., pp 151-156 (1975).

7. Carson, W.L., "Force System Synthesis for a Desired Mechanism Time Response," Proc., Third Appl. Mechanisms Conf., Oklahoma State Univ., Paper No. 16 (Nov 1973).

8. Chen, F.Y., "Isomomental Ellipsoids and the Distribution of Shaking Moments in Spatial Mechanisms," ASME Paper No. 74-DET-28 (Oct 1974).

9. Conte, F.L., George, G.R., Mayne, R.W., and Sadler, J.P., "Optimum Mechanism Design Combining Kinematic and Dynamic Force Considerations," J. Engr. Indus., Trans. ASME, 97 (2), pp 662-670 (May 1975).

10. Dix, R.C. and Agrawalla, D., "Balancing Using a General Mechanism Program," Proc., Fourth Appl. Mechanisms Conf., Oklahoma State Univ., Paper No. 24 (Nov 1975).

11. Dresig, H. and Jacobi, P., "Vollständiger Trägheitskraftausgleich von Ebenen Koppelgetreieben durch Anbringung eines Zweischlags," (Complete Inertia Force Balancing of Planar Linkages by the Addition of a Link Dyad), Maschinenbautechnik, 23 (1), pp 5 - 8 (1974).

12. Freudenstein, F., "Quasi Lumped-Parameter Analysis of Dynamical Systems," Proc., Third Appl. Mechanisms Conf., Oklahoma State Univ., Paper No. 27 (Nov 1973).

13. Gardocki, M.J. and Carson, W.L., "Force System Synthesis Using a Weighted Velocity Squared Error Criteria," Proc., Third Appl. Mechanisms Conf., Oklahoma State Univ., Paper No. 41 (Nov 1973).

14. Halter, J.M., Smith, R.E., and Carson, W.L., "Dynamic Time Response Synthesis of Mechanisms," ASME Paper No. 72-Mech-69 (Oct 1972).

15. Harmening, W.A., "Static Mass Balancing with a Torsion Spring and Four-Bar Linkage," ASME Paper No. 74-DET-29 (Oct 1974).

16. Hill, R., "Super-Smooth Superbike," Popular Science, pp 101-153 (Mar 1973).

17. Ishida, K., "Fundamental Researches on a Perfectly Balanced Rotation Reciprocation Mechanism, Report No. 1: Basic Theories of this Mechanism and Basic Constitution," Bull. JSME, 17 (103), pp 132-140 (Jan 1974).

18. Ishida, K., Matsuda, T., Nagata, S., and Oshitani, Y., "Fundamental Researches on a Perfectly Balanced Rotation-Reciprocation Mechanism, Report No. 2: Vibration on an Eccentric Geared Device of a Crankshaft Planetary Motion System and a Dynamic Balancing Machine," Bull. JSME, 17 (103), pp 141-148 (Jan 1974).

19. Ishida, K., Matsuda, T., Shinmura, S., and Oshitani, Y., "Fundamental Researches on a Perfectly Balanced Rotation-Reciprocation Mechanism, Report No. 3: Structural Analysis on Vibrationless Geared Devices of a Crankshaft Rotary Motion System and Their Vibration and Friction Loss," Bull. JSME, 17 (108), pp 818-828 (June 1974).

20. Ishida, K. and Matsuda, T., "Inertia Force and Moment Balancing of Rotation-Reciprocating Mechanisms," ASME Paper No. 74-DET-57 (Oct 1974).

21. Jungk, G., "Experimentelles Verfahren zur Ermittlung von Dynamischen Massenkräften," (An Experimental Method for the Determination of Dynamic Forces in Machines), Tagung, Dynamik und Getreibetechnik, Dresden GDR 1973, Vol. B, Paper No. 18, VEB Fachbuch verlag Leipzig (1973).

22. Koch, H., "Auswertealgorithmus zur Bestimmung der Dynamischen Maschinenkräfte aus den Messwerten" (Evaluation Algorithm for the Determination of Dynamic Forces in Machines from Test Data), Tagung, Dynamik und Getreibetechnik, Dresden GDR 1973, Vol. B, Paper No. 19, VEB Fachbuchverlag, Leipzig (1973).

23. Lowen, G.G. and Berkof, R.S., "Survey of Investigations into the Balancing of Linkages," J. Mechanisms, 3 (4), pp 221-231 (plus 11 translations of Russian and German articles) (1968).

24. Lowen, G.G. and Tepper, F.R., "Flexibility in Counterweight Design for Partial Balancing of Four-Bar Linkages: Theory of Equipollent Circles," Contribution to Festschrift in honor of 70th Birthday of Academician I.I. Artobolevskii, Teoria Mashin i Mekhanizmov, Izdatel'stvo "Nauka", Moscow, pp 177-183 (1976).

25. Lowen, G.G., Tepper, F.R., and Berkof, R.S., "The Quantitative Influence of Complete Force Balancing on the Forces and Moments of Certain Families of Four-Bar Linkages," Mechanism Mach. Theory, 9 (3/4), pp 299-323 (1974); and 10 (4), pp 361-363 (Erratum) (1975).

26. Mahig, J., "Effects of Higher Harmonies on Optimal Damping and Turning for a Tandem Compressor," ASME Paper No. 74-DET-18 (Oct 1974).

27. Nakamura, H., "A Low Vibration Engine with Unique Counter-Balance Shafts," SAE Paper No. 760111, Automotive Engr. Congr., Detroit (Feb 1976).

28. Offt, C., "Experimentelle Untersuchungen an Koppelgetreiben mit Leistungsausgleich" (Experimental Investigations of Linkages with Performance Balancing), Mechanism and Mach. Theory, 9 (2), pp 239-246 (1974).

29. Poturayev, V.N. and Franchuk, V.P., "Dynamic Calculation of the Balancing of Grate Screens of Transfer Stations of Mines" (Russian), Proc., IFTOMM Intl. Symp. Dyn. Heavy Machines Mining Metallurgical Indus., Donetsk, pp 138-144 (Sept 1974).

30. Sadler, J.P., "Balancing of Six-Bar Linkages by Nonlinear Programming," Proc., Fourth World Congr. Theory Mach. Mechanisms, Newcastle-upon-Tyne, G.B., Instn. Mech. Engr., pp 139-144 (1975).

31. Sadler, J.P. and Mayne, R.W., "Balancing of Mechanisms by Nonlinear Programming," Proc., Third Appl. Mechanisms Conf., Oklahoma State Univ., Paper No. 29 (Nov 1973).

32. Schönfeld, S., "Dynamische Synthese Ebener Koppelgetreibe mit dem Programmsystem KOGEOP" (Dynamic Synthesis of Planar Linkages with the Program KOGEOP), Maschinenbautechnik, 23 (3), pp 119-124 (1974).

33. Shchepetilnikov, V.A., "The Balancing of Bar Mechanisms with Unsymmetrical Links," Mechanism Mach. Theory, 10 (6), pp 461-466 (1975).

34. Smith, M.R., "Linkage Design: Dr. Smith Studies Ways to Minimize Inertia," Engr. Matl. Des. J., pp 23-25 (Dec 1973).

35. Smith, M.R., "Optimal Balancing of Planar Multi-Bar Linkages," Proc., Fourth World Congr. Theory Mach. Mechanisms, Newcastle-upon-Tyne, GB, Instn. Mech. Engr., pp 145-149 (1975).

36. Speckhart, F.H. and Wright, D., "Balancing Slider-Crank Mechanisms," ASME Paper No. 75-DE-32 (Apr 1975).

37. Spreitzer, G., "Über die Bewegung des Gesamptschwerpunktes beim Fünfgelenkgetreibe mit Doppelantreib" (On the Motion of the Total Center of Mass of a Five-Bar Linkage with Two Drive Cranks), Acta Mech., 16, pp 35-43 (1973).

38. Stevensen, Jr., E.N., "Balancing of Machines," J. Engr. Indus., Trans. ASME, 95 (2), pp 650-656 (May 1973).

39. Tepper, F.R. and Lowen, G.G., "A New Criterion for Evaluating the RMS Shaking Moment in Unbalanced Planar Mechanisms," Proc., Third Appl. Mechanisms Conf., Oklahoma State Univ., Paper No. 11 (Nov 1973).

40. Tepper, F.R. and Lowen, G.G., "On the Distribution of the RMS Shaking Moment of Unbalanced Planar Mechanisms: Theory of Isomomental Ellipses," J. Engr. Indus., Trans ASME, 95 (3), pp 665-671 (Aug 1973).

41. Tepper, F.R. and Lowen, G.G., "Shaking Force Optimization of Four-Bar Linkage with Adjustable Constraints on Ground Bearing Forces," J. Engr. Indus., Trans. ASME, 97 (2), pp 643-651 (May 1975).

42. Tepper, F.R. and Lowen, G.G., "Two General Rules for Full Force Balancing of Planar Linkages," Proc., Third Appl. Mechanisms Conf., Oklahoma State Univ., Paper No. 10 (Nov 1973).

LITERATURE REVIEW

survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

The series of review articles on underwater fluid-structure interaction and ship hull vibration continues in this issue of the DIGEST. L.H. Chen and M. Pierucci discuss acoustically-applied forces including sound radiation and scattering, structural vibration and shock response, flow-induced noise, hydrodynamic divergence and flutter, boundary layer stability, and propeller induced forces. J.J. Jensen and N.F. Madsen discuss methods of solution in their third article on ship hull vibration.

UNDERWATER FLUID-STRUCTURE INTERACTION
PART III: ACOUSTICALLY-APPLIED FORCES

L.H. Chen* and M. Pierucci**

Abstract - Fluid-structure interaction encompasses a broad spectrum of technical areas of interest in engineering application. This discussion is limited to "underwater" applications and includes the following topics: sound radiation and scattering, structural vibration and shock response, flow-induced noise, hydrodynamic divergence and flutter, boundary layer stability, and propeller-induced forces. The common thread linking these technologies, namely, the interaction phenomenon, is stressed. An attempt has been made to clarify some of the terminology within these diverse technical areas.

The acoustic field can be handled in three ways: steady-state scatter, transient scatter, and transient shock response. In steady-state acoustic scatter, the force field can be broken up into three components. The governing equations are as follows.

$$
\begin{aligned}
&D_S[w] = \overset{i}{p} + \overset{s}{p}_1 + \overset{s}{p}_2(w^*) \\
&\nabla^2\phi + k^2\phi = 0 \\
&\phi = \phi_1 + \phi_2 \\
&w^* = u = \overset{i}{u} + \overset{s}{u}_1 + \overset{s}{u}_2 \\
&\overset{s}{p}_1 = -i\omega\rho\phi_1 \;,\; \overset{s}{u}_1 = \frac{\partial\phi_1}{\partial n} \\
&\overset{s}{p}_2 = -i\omega\rho\phi_2 \;,\; \overset{s}{u}_2 = \frac{\partial\phi_2}{\partial n}
\end{aligned}
\tag{25}
$$

The superscripts i and s denote the incident and scattered fields respectively. The subscripts 1 and 2 divide the scattered field into rigid and elastic components, as defined in equation (8), which is repeated as the first equation in the set above. According to the definition of rigid scatter:

$$\overset{i}{u} + \overset{s}{u}_1 = 0 \quad \text{or} \quad w^* - \overset{s}{u}_2 = 0 \tag{26}$$

For the transient case of shock response, particularly if approximate or decoupling methods are used, the acoustic field usually consists of two components. The governing equations are as follows.

$$
\begin{aligned}
&D_S[w] = \overset{i}{p} + \overset{s}{p}(w^*) \\
&\nabla^2\phi = \frac{1}{c^2}\phi^{**} \\
&w^* = u = \overset{i}{u} + \overset{s}{u} \\
&\overset{s}{p} = \rho\phi^* \;,\; \overset{s}{u} = \frac{\partial\phi}{\partial n}
\end{aligned}
\tag{27}
$$

The interaction pressure $\overset{s}{p}(w^*)$ is called the scattered or radiated, pressure.

In two Russian references for which English translations are available [42, 57], the components of the acoustic field are described by equations (28).

$$
\begin{aligned}
&D_S[w] = \overset{i}{p} + \overset{s}{p}_1 + \overset{s}{p}_2(w^*) \\
&\nabla^2\phi = \frac{1}{c^2}\phi^{**} \\
&\phi = \phi_1 + \phi_2 \\
&w^* = u = \overset{i}{u} + \overset{s}{u}_1 + \overset{s}{u}_2 \\
&p_I = \overset{i}{p} + \rho\overset{*}{\phi}_1 \\
&p_{II} = \rho\overset{*}{\phi}_2
\end{aligned}
\tag{28}
$$

The diffraction pressure or load of the first category is p_I; p_{II} is the radiated pressure or load of the second category. The components of the acoustic field are essentially the same as those for the steady-state case shown in equations (25). The potential ϕ_1 applies to the field in which the structure is rigid and immobile in space. The potential ϕ_2 accounts for

* Manager of Technology Development
**Principal Engineer
General Dynamics Electric Boat Div., Groton, CT 06340

PRECEDING PAGE BLANK-NOT FILMED

the elastic motion of the structure, including the rigid body motion.

ACOUSTIC SCATTER

The steady-state case of acoustic scatter, in which the scattered field is considered rigid, has been extensively studied; few reports have appeared on elastic scatter, however. Methods described in SOUND RADIATION (see Part II of this article in the May 1977 issue of the Shock and Vibration Digest) apply to scatter problems.

Considerable analytical work has been reported for the transient case -- primarily the interaction of shell structure with a shock wave -- including the plane-strain response of a cylindrical shell to an incident plane step wave [13] and the early-time three-dimensional response of a cylindrical shell interacting with a spherical wave [28]. The interaction of shock waves with fluid-loaded cylindrical shell structures has been reviewed [41]. Analytical results useful for the study of the dynamic strength of ship structures have been published [42, 57]. The separation of rigid body motion from diffraction pressure provides physical insight into interaction phenomena.

A good general formal method for dealing with the transient response of complex structures has not yet appeared because of the difficulties associated with the computation required. In principle, the fluid finite element method used with structural finite elements is a general tool; however, it has been applied to only a few simple problems [31].

The simple source method has been applied to the transient case [21]. Three numerical examples were given to demonstrate the versatility of the method, but the results are correct only for small time intervals. It was also noted that the transient counterpart of the Helmholtz integral formulation is the arbitrary time-dependent Kirchhoff integral theorem. Special numerical techniques such as the finite-difference method have also been used [6].

Shock Response

No formal method is available for treating practical structures, but three decoupling schemes have been used to describe shock response. The object of decoupling methods is to bypass the wave equation -- i.e., the second, third, and fourth expressions of equations (27) -- by assuming a relationship between the scattered pressure $\overset{s}{p}$ and its associated velocity $\overset{s}{u}$. The three schemes are described as follows.

- plane wave approximation (PWA)

$$\overset{s}{u} = w^* - \overset{i}{u} = \frac{1}{\rho c}\,\overset{s}{p} \qquad (29)$$

- virtual mass approximation (VMA)

$$\overset{s}{u}{}^* = w^{**} - \overset{i}{u}{}^* = \frac{1}{M}\,\overset{s}{p} \qquad (30)$$

- doubly asymptotic approximation (DAA)

$$\overset{s}{u}{}^* = \frac{1}{\rho c}\,\overset{s}{p}{}^* + \frac{1}{M}\,\overset{s}{p} \qquad (31)$$

The PWA is sometimes called the Taylor approximation or the radiation damping approximation because the ρc term represents the radiation damping of a plane wave in free space. The PWA gives a good approximation of the early, or high frequency, non-oscillatory response of the interaction. In the VMA scheme, the virtual or added mass M is obtained from the incompressible fluid theory described in STRUCTURAL VIBRATIONS (see Part II of this article). It provides a good approximation of the later, or low frequency, oscillatory response of the interaction. In the DAA scheme, first proposed by Geer [24], the PWA and the VMA schemes are combined. Refinements to PWA include cylindrical wave and spherical wave approximations. Numerical comparisons of these decoupling schemes have been published [33], and a more refined scheme called the inertial-damping collocation approximation, has been proposed [8].

The decoupling schemes, particularly the DAA method, have been extensively studied for the purpose of developing a versatile tool for predicting the dynamic response of a complex structure with reasonable accuracy and computational effort.

A dynamic design and analysis method, called DDAM developed in the early 1960s [4] has been used in the dynamic design of naval shipboard equipment for well over a decade. It is a decoupling method in the sense that the structure is analyzed as if it were in vacuo; the shock spectrum is obtained primarily from experiments.

REFERENCES

1. Allik, H. and Hughes, T.J.R., "Finite Element Method for Piezoelectric Vibration," Intl. J. Numer. Methods Engr., 2, pp 151-157 (1970).

2. Allik, H., Cacciatore, P.J., Gauthier, R., and Gordon, S.F., "MARTSAM IV - A Version of GENSAM," General Dynamics, Electric Boat Division Report U440-74-043, Vols. I, II, III, IV (May 1974). (approval of NAVSEA required.)

3. Baylor, J.L., "Operator Singularities of Integral Equations of Linear Acoustics," J. Acoust. Soc. Amer., 42 (5), p 1204 (Nov 1967).

4. Belsheim, R.O. and O'Hara, G.J., "Shock Design of Shipboard Equipment," Part I (unclassified NAVSHIPS Rept. No. 250-423-30 (May 1961)).

5. Benjamin. B.T., "Effect of a Flexible Boundary on Hydrodynamic Stability," J. Fluid Mech., 9, pp 513-532 (1960).

6. Berger, B.S., "Reflected and Radiated Acoustic Pressure from an Elastic Shell of Revolution," Rept. Contract No. N00014-67-A0239-0020, Univ. Maryland (Oct 1975).

7. Bleich, H.H. and Baron, M.L., "Free and Forced Vibrations of an Infinitely Long Cylindrical Shell in an Infinite Acoustic Medium," J. Appl. Mech., Trans. ASME, 21, pp 167-177 (1954).

8. Bleich, H.H., DiMaggio, F.L., and Baron, M.L., "On Uncoupling Fluid-Structure Interaction Problems," Part II, Weidlinger Assoc. Rept. ONR Contract N00014-72-C-0119 (July 1973).

9. Blick, E.F., "Skin Friction Drag Reduction by Compliant Coatings," Paper F2, Intl. Conf. Drag Reduction, Cambridge (Sept 1974).

10. Boggs, F.W. and Frey, H.R., "The Effect of a Lamiflo Coating on a Small Planing Hull Having Zero Deadrise," U.S. Rubber Co. Rept. (June 1961).

11. Breslin, J.P., "Techniques for Estimating Vibratory Forces Generated by Propellers," Tech. Res. Bull. No. 1-34, Hydrodynamics Committee, Soc. Naval Architects Marine Engr. (1975).

12. Brown, R., "Turbulent Pressure Spectrum Measurements on a Compliant Surface," Fourth Biannual Symp. Turbulence in Liquids, Univ. Missouri-Rolla (Sept 1975).

13. Carrier, G.F., "The Interaction of an Acoustic Wave and an Elastic Cylindrical Shell," Tech. Rept. 4, Contract Nonr-35810, Brown Univ. (1951).

14. Chen, L.H., "A Matrix Method of Analysis of Structure-Fluid Interaction Problems," ASME Paper No. 61-WA-220 (Nov 1961).

15. Chen, L.H. and Schweikert, D.G., "Sound Radiation from an Arbitrary Body," J. Acoust. Soc. Amer., 35 (10), pp 1626-1632 (1963).

16. Davies, H.G., "Sound From Turbulent Boundary Layer Excited Panels," J. Acoust. Soc. Amer., 49 (3), pp 878-889 (1971).

17. DiMaggio, F.L., "Dynamic Response of Fluid-Filled Shells," Shock Vib. Dig., 7 (5), pp 5-12 (May 1975).

18. Dowell, E.H., "Noise or Flutter or Both?" J. Sound Vib., 11 (2), pp 159-180 (1970).

19. Engin, A.E. and Engin, A.W., "Survey of the Dynamic Response of Spherical and Spheroidal Shells," Shock Vib. Dig., 7 (3) (1975).

20. Everstine, G.C., Schroeder, E.M., and Marcus, M.S., "The Dynamic Analysis of Submerged Structures," Fourth NASTRAN Users Colloq., Langley Res. Ctr. (Sept 1975).

21. Farn, C.L.S. and Huang, H., "Transient Acoustic Fields Generated by a Body of Arbitrary Shape," J. Acoust. Soc. Amer., 43 (2), pp 252-257 (1968).

22. Feit, D., "Flow Noise Characteristics of Elastic Plates Excited by Boundary Layer Turbulence," Cambridge Acoust. Assoc. Rept. No. U-279-199 (Apr 1968).

23. Ffowcs-Williams, J.E., "Reynold Stress near a Flexible Surface Responding to Unsteady Air Flow," Bolt Beranek and Newman Rept. No. 1138 (June 1964).

24. Geers, T.L., "Residual Potential and Approximate Methods for Three Dimensional Fluid-Structure Interaction Problems," J. Acoust. Soc. Amer., 49 (5), pp 1505-1510 (1971).

25. Hansen, R.J. and Hunston, D.L., "An Experimental Study of Turbulent Flows Over Compliant Surfaces," J. Sound Vib., 34 (3), pp 297-308 (1974).

26. Haviland, J.K. and Cooley, D.E., Structural Mechanics Computer Programs (W. Pilkey, K. Saezalski, and H. Schaeffer, Eds.), Univ. Virginia Press (1974).

27. Henderson, F.M., "A Structure-Field Interaction Capability for the NASA Structural Analysis (NASTRAN) Computer Program," DTNSRDC Rept. No. 3962 (Aug 1972).

28. Huang, H. and Wang, Y.F., "Early-Time Interaction of Spherical Acoustic Waves and a Cylindrical Elastic Shell," J. Acoust. Soc. Amer., 50, pp 885-891 (1971).

29. Izzo, A.J., "An Experimental Investigation of the Turbulent Characteristics of a Boundary Layer Flow over a Vibrating Plate," Dissertation submitted to Univ. Connecticut (1969).

30. Junger, M.C., "Vibrations of Elastic Shells in a Fluid Medium and the Associated Radiation of Sound," J. Appl. Mech., Trans. ASME, 19 (1) (Mar 1952).

31. Kalinowski, A.J., "Fluid Structure Interaction," in Shock and Vibration Computer Programs - Reviews and Summaries (W. and B. Pilkey, Eds.), Naval Res. Lab., Wash., D.C., pp 405-452 (1975).

32. Kline, R.G. and Daidola, J.C., "Ship Vibration Prediction Methods and Evaluation of Influence of Hull Stiffness Variation on Vibratory Response," Rept. SSC-249, Ship Struc. Comm., U.S. Coast Guard, Wash., D.C., pp 2-11 (1975).

33. Klosner, J.M., "Response of Shells to Acoustic Shocks," Shock Vib. Dig., 8 (5), pp 3-13 (1976).

34. Krämer, M.O., "Boundary Layer Stabilization by Distributed Damping," J. Amer. Soc. Nav. Engr., 72, p 25 (1960).

35. Landhal, M.T., "On the Stability of a Laminar Incompressible Boundary Layer over a Flexible Surface," J. Fluid Mech., 13 (1962).

36. Laufer, J. and Maestrello, L., "The Turbulent Boundary Layer over a Flexible Surface," The Boeing Co. Document No. D6-9708 (1963).

37. Leibowitz, R.D., "Vibroacoustic Response of Turbulence Excited Thin Rectangular Finite Plates in Heavy and Light Fluid Media," J. Sound Vib., 40 (4), pp 441-495 (1975).

38. Leibowitz, R.C., "Experimental and Theoretical Foundations for Modern Turbulence - Vibroacoustic Research. A Decade of Exploration 1956-1965," DTNSRDC Tech. Note SAD 536-194 (Nov 1975).

39. Lin, C.C., The Theory of Hydrodynamic Stability, Cambridge Univ. Press (1967).

40. McMahon, J.F., "Surface Wave Characteristics for the Flow of an Inviscid Fluid Over an Elastic Surface," Penn. State Univ., ORL Rept. No. TN502-02 (1970).

41. Menton, R.T. and Magrab, E.B., "Interaction of Acoustic Pulses with Fluid-Loaded Shell Structures," Shock Vib. Dig., 5 (12), pp 2-12 (1973).

42. Mnev, Y.N. and Pertsev, A.K., "Hydroelasticity of Shells," Air Force Systems Command Rept. FTD-MT-24-119-71 (1971).

43. Morfey, C.L., "Rotating Blades and Aerodynamic Sound," J. Sound Vib., 28 (3), pp 587-618 (1973).

44. Neubert, V.H., "Inertia Matrices for Finite Elements," Shock and Vibration Computer Programs - Reviews and Summaries (W. and B. Pilkey, Eds.), Naval Res. Lab., Wash., D.C., pp 625-645 (1975).

45. Pierucci, M., "Hydrodynamic Instabilities of a Layered Medium in the Presence of a Flow Field," J. Acoust. Soc. Amer., 58, p 521 (1975).

46. Ross, D., "Vortex Shedding Sounds of Propellers," Bolt Beranek and Newman Rept. No. 1115 (1964).

47. Schenck, H.A., "Improved Integral Formulation for Acoustic Radiation Problems," J. Acoust. Soc. Amer., 44 (1), pp 41-58 (July 1968).

48. Smith, R.R., Hunt, J.T., and Barach, D., "Finite Element Analysis of Acoustically Radiating Structures with Applications to Sonar Transducers," J. Acoust. Soc. Amer., 54 (5), pp 1277-1288 (1973).

49. Smith, R.R., Barach, D., McCleary, L.E., and Johnson, J.L., "A Finite Element Model for Analyzing Self-Noise Levels in Geophysical Towed Line Arrays," ASME Paper No. 76-PVP-27 (May 1976).

50. Strawderman, W.A., "Turbulence Induced Plate Vibrations: An Evaluation of Finite and Infinite Plate Models," J. Acoust. Soc. Amer., 46 (5), pp 1294-1307 (1969).

51. Tokita, N. and Boggs, F.W., "Final Report on Theoretical Study of Compliant Coatings to Achieve Drag Reduction on Underwater Vehicles," U.S. Rubber Co., Rept. No. NR062-241 (1962).

52. Tsakonas, S., Jacobs, W.R., and Ali, M.R., "An Exact Linear-Surface Theory for a Marine Propeller in a Non-Uniform Flow Field," J. Ship Res. (Dec 1973).

53. VonWinkle, W.A., "An Evaluation of a Boundary Layer Stabilization Coating," Underwater Sound Lab Memo No. 922-111-61 (1961).

54. Vorus, W.S., "An Integrated Approach to the Determination of Propeller-Generated Vibratory Forces Acting on a Ship Hull," Univ. Michigan Rept. No. 072 (1971).

55. Warburton, G.B., "Vibration of a Cylindrical Shell in an Acoustic Medium," J. Mech. Engr. Sci., 3, p 69 (1961).

56. White, F.M. and Quaglieri, R.E., "A Theoretical Estimate of Turbulent Wall Pressure Fluctuations on a Compliant Boundary," U.S. Navy Underwater Sound Lab. Rept. No. 767 (1966).

57. Zamyshiyayev, V.B. and Yakovelev, Y.S., "Dynamic Loads in Underwater Explosion," Rept. AD-757 183, NTIS, U.S. Dept. of Commerce, Springfield, VA (Feb 1973).

58. Zienkiewicz, O.C. and Newton, R.E., "Coupled Vibrations of a Structure Submerged in a Compressible Fluid," Proc. Intl. Symp. Finite Element Tech., Intl. Assoc. Ship Struc., Univ. Stuttgart, Ger. (June 1969).

A REVIEW OF SHIP HULL VIBRATION
PART III: METHODS OF SOLUTION

J. Juncher Jensen and Niels Fl. Madsen*

Abstract - This paper is a review of the analytical and numerical tools used to calculate hull vibrations. Mathematical Models were described in the first part. The second part on Modeling of Physical Phenomena contained descriptions of mathematical models of the hull. Numerical determination of the equations of motion is discussed in the third part -- Methods of Solution. The fourth part, Comparison of Beam Models, is a review of methods used to solve the equations of motion; an example problem illustrates various principles.

Solution of the equations of motion frequently involves determining undamped natural frequencies and corresponding mode shapes. The forced steady-state or transient response due to propeller-, engine-, or wave-induced forces can be calculated using the normal mode approach [13, 25, 28, 116]. When damping is assumed to be a linear combination of the distributions of mass and stiffness, the equations of motion reduce to uncoupled one-dimensional equations because of orthogonality conditions

$$\frac{\partial^2 q_i}{\partial t^2} + 2\omega_i \frac{C_i}{C_{ci}} \frac{\partial q_i}{\partial t} + \omega_i^2 q_i = f_i \qquad i = 1, 2, 3... \tag{23}$$

For the mode i, the expression $q_i(t)$ denotes the time-dependent generalized coordinate; ω_i is the frequency; $\frac{C_i}{C_{ci}}$ is the ratio of damping to critical damping; and $f_i(t)$ is the time-dependent force component. The general solution to equation (23) can be found in any elementary vibration text.

In some numerical procedures, the forced response is determined directly for selected frequencies. An iterative method is used [95] in the case of nonlinear damping. Calculation of natural frequencies for the undamped system generally results in a semi-definite eigenvalue problem [34] because the rigid-body modes do not introduce any elastic energy into the system.

*Department of Ocean Engineering, The Technical University of Denmark, 2800 Lyngby, Denmark

BEAM MODELS

Several numerical methods have been used to solve the eigenvalue problem for the single-beam idealization. The classical Stodola method, originally used as a graphical solution technique, has been adapted to the computer [15, 112]. In operator form, the eigenvalue problems can be written as

$$L[Z] = \lambda N[Z] \ , \qquad U_n[Z] = 0 \tag{24}$$

$L[\ ]$ is a linear differential matrix operator; $N[\ ]$ and $U_n[\ ]$ are linear algebraic matrix operators for which $U_n[\ ]$ defines the boundary conditions: λ is the squared natural frequency; and Z is a vector representing generalized displacements. In operator form the normal Stodola procedure for the i^{th} iterate is as follows.

Calculate Z_i^* *from the boundary value problem*

$$L[Z_i^*] = N[Z_{i-1}] \ , \quad U_n[Z_i] = 0$$

Normalize Z_i^* with

$$\alpha_i = \left(\int_0^L Z_i^* N[Z_i^*] \, dx \right)^{1/2} \qquad Z_i^+ = Z_i^* / \alpha_i$$

Make Z_i^+ orthogonal at lower modes

$$Z_i = Z_i^+ - \sum_{j=1}^{s} y_j \int_0^L Z_i^+ N[y_j] \, dx$$

The y_j denotes the j^{th} eigenvector already found. After a few iterations Z_i and $1/\alpha_i$ converge to the $(s+1)^{th}$ eigenvector, which is y_{s+1}, and the corresponding squared natural frequency λ_{s+1}, respectively. The boundary conditions of the free-free beam correspond to orthogonalization against rigid body modes; so that the method can be used to determine the positive eigenvalues even though the eigenvalue problem is semi-definite.

PRECEDING PAGE BLANK-NOT FILMED

The Rayleigh-Ritz approximation has been useful for calculating vertical vibrations in which the three-dimensional flow around the hull is accounted for [93]. The Rayleigh-Ritz method generally involves a matrix eigenvalue problem

$$[\,[K] - \lambda [M]\,]\ \{Q\} = \{0\} \qquad (25)$$

The mass matrix [M] is a full, symmetric, and positive definite matrix; the stiffness matrix [K] is full, symmetric, and semi-definite. The unknown quantities weighting the coordinate functions are assembled in a vector $\{Q\}$; λ denotes the unknown squared natural frequencies.

The lumped-parameter method can also be used in the case of semi-definite systems [92]. The flexibility influence coefficients are derived from a reference position defined by the rigid-body motion. The kinetic energy expression must be written in terms of absolute velocities. The modified mass and stiffness matrices in the resulting eigenvalue problem are full, symmetric, and positive definite.

The transfer matrix method, originally applied to bending vibration by Myklestad [94], has been used to solve the equations of motion [1, 3, 48, 97, 98]. The mass is concentrated in a number of lumps at stations distributed along the hull girder. The stiffness properties are assumed to be uniform in the massless fields between the stations. Equilibrium conditions for each station and field are expressed in a set of linear algebraic equations. The effects of external forces and arbitrary damping can easily be included. Variants of the method have been developed [18, 97] because solutions are occasionally numerically unstable.

COMPLEX STRUCTURES

The finite element method is probably the most convenient procedure when detailed information is required concerning the vibratory behavior of the hull [13, 107] or the interaction between the hull and superstructures [28, 116]. Several types of finite elements are used. The aft end section can be idealized by a two- or three-dimensional model consisting of membrane and bar elements rigidly connected to the forepart of the ship. The ship, including the effect of shear, can be idealized by beam elements (see Fig. 3). A three-dimensional model of the entire ship must be used to model coupled horizontal-torsional vibrations.

Computer calculations of the finite element method are very time-consuming. For this reason, the normal mode approach has been widely used [13, 25, 28, 116]. If a damping mechanism other than damping proportional to critical damping is required, or if response for only a few selected frequencies is necessary, the equations of motion are, as a rule, solved directly. Forced, undamped response has been investigated with a three-dimensional finite element analysis of the propeller blade frequency only [107]. The mode superposition method has been extended to include arbitrary damping [117].

The mass and stiffness matrices in finite element vibration calculations are generally large order symmetric and banded matrices. Reviews on the methods available to solve such eigenvalue problems have been published [11, 26]. The problem can be considerably reduced by various condensation techniques [20, 27, 109].

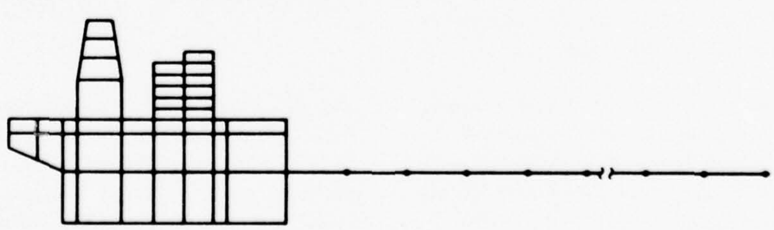


Figure 3. Two-dimensional Finite Element Idealization of a Large Tanker.

REFERENCES

1. Aertssen, G. and deLembre, R., "Calculation and Measurement of the Vertical and Horizontal Vibration Frequency of a Large Ore Carrier," Trans. North East Coast Inst. Engr. Shipbldg., 86, pp 9-12 (1967-70).

2. Aertssen, G. and deLembre, R., "A Survey of Vibration Damping Factors Found from Slamming Experiments on Four Ships," Trans. North East Coast Inst. Engr. Shipbldg., 87, pp 83-86 (1970-71).

3. Anderson, G. and Norrand, K., "A Method for the Calculation of Vertical Vibration with Several Nodes and Some Other Aspects of Ship Vibration," Trans. RINA, 111, pp 367-383 (1969).

4. Bell, A.O. and Taylor, K.V., "Wave-Exctied Hull Vibration, Measurements on a 47,000 d.w.t. Tanker," Shipping World and Shipbuilder, 161, pp 412-419 (1968).

5. Bett, C.V., Bishop, R.E.D., and Price, W.G., "A Survey of Internal Hull Damping," Trans. RINA, preprint (w2) (1976).

6. Bishop, R.E.D. and Taylor, R.E.,"On Wave-Induced Stress in a Ship Executing Symmetric Motions," Phil. Trans. Roy. Soc. Lond., A275, pp 1-32 (1973).

7. Bourceau, G. and Volcy, C.G., "Forced Vibration Resonators and Forced Vibration of the Hull," Intl. Shipbldg. Prog., 18, pp 243-271 pp 275--294 (1971).

8. Breslin, J.P., "Theoretical and Experimental Techniques for Practical Estimation of Propeller-Induced Vibratory Forces," Trans. Soc. Naval Architects Marine Engr., 78, pp 23-40 (1970).

9. Breslin, J.P., "Exciting Force Operators for Ship Propellers," AIAA J. Aeronuat., 5 (3), pp 85-90 (1971).

10. Breslin, J.P., "Techniques for Estimating Vibratory Forces Generated by Propellers," Tech. and Res. Bull., Soc. Naval Architects Marine Engr. (Jan 1975).

11. Brönlund, O.E., "Eigenvalues of Large Symmetric Matrices," Proc. Fourth Intl. Ship Struc. Cong., Tokyo, pp 283-287 (1970).

12. Burrill, L.C., Robson, W., and Towsin, R.L., "Ship Vibration: Entrained Water Experiments," Trans. RINA, 104, pp 415-435 (1962).

13. Catley, D. and Norris, C., "Theoretical Prediction of the Vertical Dynamic Response of Ship Structures Using Finite Elements and Correlation with Ship Mobility Measurements," Proc. Eleventh Symp. Naval Hydrodynamics, Dept. Mech. Engr., Univ. College London, pp VI.23-VI.38 (Mar-Apr 1976).

14. Chowdhury, P.C., "Fluid Finite Elements for Added-Mass Calculations," Intl. Shipbldg. Prog. 19 (217), pp 302-309 (1972).

15. Collatz, L., "Eigenwertaufgaben mit technischen Anwendungen," Akademische Verlagsgesellschaft, Geest and Portig, 2. Auflage, Leipzig (1963).

16. Cowper, G.R., "The Shear Coefficient in Timoshenko's Beam Theory," J. Appl Mech., Trans. ASME, 33, p 335 (1966).

17. Csupor, D.A., "Zur Theorie un Berechnung der freien ungedämpften Schwingungen des Schiffskörpers," Diss. TH Hannover (1956).

18. Dawson, B. and Davies, M., "An Addition to Myklestad's Method Giving Convergence to a Natural Frequency," J. Ship Res., 19 (2), pp 130-132 (1975).

19. Frank, W., "Oscillating of Cylinders in or below the Free Surface of Deep Fluids," NSRDC, Washington, D.C., Rep. No. 2375 (1967).

20. Fried, I., "Condensation of Finite Element Eigenproblems," AIAA J., Tech. Note, 10 (11), pp 1529-1530 (1972).

21. Frivold, H., "Solid Boundary Factors for the Afterbody of an LNG Carrier," Norwegian Maritime Res., 4 (1), pp 16-20 (1976).

22. van Gent, W., "Unsteady Lifting-Surface Theory for Ship Screws: Derivation and Numerical Treatment of Integral Equation," J. Ship Res., 19 (4), pp 243-253 (1975).

23. Goodman, R.A., "Wave-Excited Main Hull Vibration in Large Tankers and Bulk Carriers," Trans. RINA, 113, pp 167-184 (1971).

24. Grim, A., "Hydrodynamic Masses," Schiffstechnik, 5 (29) (1958).

25. van Gunsteren, F.F., "Springing, Wave-Induced Ship Vibration," Intl. Shipbldg. Prog., 17 (195), pp 333-347.

26. Gupta, K.K., "Recent Advances in Numerical Analysis of Structural Eigenvalue Problems," in Theory and Practice in Finite Element Structural Analysis, Proc. 1973 Tokyo Seminar Finite Element Anal., pp 249-271.

27. Guyan, R.J., "Reduction of Stiffness and Mass Matrices," AIAA J., 3 (2), p 380 (1968).

28. Hansen, H.R. and Skaar, K.T., "Hull and Superstructure Vibrations, Design Calculation by Finite Elements," Proc. Symp. High Powered Propulsion Large Ships, Netherlands Ship Model Basin, Wageningen (1974).

29. Hart, H.H.'t, "Hull Vibrations of the Cargo-Liner Koudekerk," Intl. Shipbldg. Prog., 18 (206), pp 373-383 (1971).

30. Havelock, T.H., "Ship Vibrations: the Virtual Inertia of a Spheroid in Shallow Water," Quart. Trans. INA, 95 (1953).

31. Hirowatari, T., "Magnification Factors in the Higher Modes of Ship Vibration," JSNA-Japan, 113, pp 156-168 (1963).

32. Huse, E., "Hull Vibration and the Measurements of Propeller-Induced Pressure Fluctuations," Intl. Shipbldg. Prog., 17 (187), pp 87-95 (1970).

33. Huse, E., "Pressure Fluctuations on the Hull-Induced by Cavitating Propellers," Norwegian Ship Model Expt. Tank, Publ. No. 111 (Mar 1972).

34. Hylarides, S., "Lowest Natural Frequencies of Structures with Rigid-Body Degrees of Freedom," J. Ship Res., 12 (2), pp 131-136 (1968).

35. Hylarides, S., "Finite Element Technique in Ship Vibration Analysis," Intl. Shipbldg. Prog., 15 (169), pp 328-338 (1968).

36. Hylarides, S., "Recent Developments in Hull and Shaft Vibration Analysis," Intl. Shipbldg. Prog., 17 (190), pp 185-190 (1970).

37. Hylarides, S., "Hull Resonance: An Explanation of Excessive Vibrations," Intl. Shipbldg. Prog., 21 (236), pp 89-99 (1974).

38. Hylarides, S., "Damping in Propeller-Generated Ship Vibrations," Netherlands Ship Model Basin, No. 468 (1974).

39. Proc. First International Ship Structures Congress, Glasgow (1961).

40. Proc. Second International Ship Structures Congress, Delft, The Netherlands (1964).

41. Proc. Third International Ship Structures Congress, Oslo, Norway (1967).

42. Proc. Fourth International Ship Structures Congress, Tokyo, Japan (1970).

43. Proc. Fifth International Ship Structures Congress, Hamburg, West Germany (1973).

44. Johnson, A.J., "Vibration Tests of All-Welded and All-Riveted 10,000 Ton Dry Cargo Ship," Trans. North East Coast Inst. Engr., 67, pp 205-276 (1950-51).

45. Johnson, A.J., Ayling, P.W., and Couchman, A.J., "On the Vibration Amplitudes of Ships' Hulls," Trans. Instn. Engr. Shipbldg. Scotland, 105, pp 301-387 (1962).

46. Joosen, W.P.A. and Spangenberg, J.A., "On the Longitudinal Reduction Factor for the Added Mass of Vibrating Ships with Rectangular Cross-Section," Netherlands Research Centre, TNO, No. 40S (1961).

47. Kagawa, K. and Ohtaka, K., "Higher Mode Vertical Vibration of Giant Tanker," 2nd Rep., JSNA-Japan, 128, pp 295-309 (1970).

48. Kagawa, K. and Miyamoto, M., "Hull Vibration of Container Ship," Mitsubishi Tech. Bull. No. 81 (1972).

49. Kawakami, M. and Kiso, T., "On the Wave-Induced Ship Hull Vibration," JSNA-West Japan No. 51 (Mar 1976).

50. Kline, R.G. and Daidola, J.C., "Ship Vibration Prediction Methods and Evaluation of Influence of Hull-Stiffness Variation on Vibratory Response," Ship Struc. Committee, U.S. Coast Guard No. 249 (1975).

51. Kline, R.G. and Daidola, J.C., "Bibliography for Ship Vibration Prediction Methods and Evaluation of Influence of Hull-Stiffness Variation on Vibratory Response," Ship Struc. Committee, U.S. Coast Guard No. 250 (1975).

52. Kruppa, C., "Beitrag zum Problem der hydrodynamischen Trägheitsgrössen bei elastichen Schiffsschwingungen," Schiffstechnik, 9 (45), pp 38-60 (1962).

53. Kuiper, G., "Some Remarks on Lifting Surface Theory," Intl. Shipbldg. Prog., 18 (199), pp 131-148 (1971).

54. Kumai, T., "Shearing Vibrations of Ships," Eur. Shipbldg., 5 (2), pp 32-37 (1956).

55. Kumai, T., "The Effect of Loading Conditions on the Natural Frequency of Hull Vibration," Rep. R.I.A.M., Kyushu Univ. Japan, 5 (17), pp 9-20 (1957).

56. Kumai, T., "Damping Factors in the Higher Modes of Ship Vibration," Eur. Shipbldg., 7 (1), pp 29-34 (1958).

57. Kumai, T., "Added Mass Moment of Inertia Induced by Torsional Vibration of Ships," Rep. R.I.A.M., Kyushu Univ. Japan, 7 (28), pp 233-244 (1959).

58. Kumai, T., "Some Correction Factors for the Virtual Inertia Coefficient for the Horizontal Vibrations of a Ship," Rep. R.I.A.M., Kyushu Univ. Japan, 9 (33), pp 17-25 (1961).

59. Kumai, T. et al, "Measurement of Propeller Forces Exciting Hull Vibration by Use of Self-Propelled Model," Rep. R.I.A.M., Kyushu Univ. Japan, 9 (33), pp 1-15 (1961).

60. Kumai, T., "Some Aspect of the Propeller Bearing Forces Exciting Hull Vibration of a Single Screw Ship," Rep. R.I.A.M., Kyushu Univ. Japan, 9 (33), pp 27-34 (1961).

61. Kumai, T., "The Effect of Distribution of Load upon the Virtual Inertia Coefficient in the Vertical Vibration of a Ship," Rep. R.I.A.M., Kysuhu Univ. Japan, 10 (37) (1962).

62. Kumai, T., "On the Three-Dimensional Correction Factor for the Virtual Inertia Coefficient in the Vertical Vibration of Ships," JSNA-Japan, 112 (Dec 1962).

63. Kumai, T. and Ochi, Y., "On the Vibration of Ships in Wave," Rep. R.I.A.M., Kyushu Univ. Japan, 11 (40), pp 13-19 (1963).

64. Kumai, T., "On the Apparent Mass of Cargo Oil in Vibration of a Tanker," Rep. R.I.A.M., Kyushu Univ. Japan, 13 (46), pp 69-78 (1965).

65. Kumai, T., "Effect of Shear Deflection and Rotatory Inertia on the Damping of the Flexural Vibration of a Ship Hull," Rep. R.I.A.M., Kyushu Univ. Japan, 13 (46), pp 61-68 (1965).

66. Kumai, T. and Sakurada, Y., "On the Measurements of Propeller Surface Force of the Self-

67. Kumai, T., "A Method for Evaluating the Three-Dimensional Reduction Factor of the Virtual Mass in the Vertical Vibration of Ships," Japan Shipbldg. Marine Engr., 1 (3), pp 15-21 (1966).

68. Kumai, T., "Vibration of a Mammoth Tanker with Special Consideration to Athwartship Flexibility," Eur. Shipbldg., 16 (3), pp 50-53 (1967).

69. Kumai, T., "On the Estimation of Natural Frequencies of Vertical Vibration of Ships," Rep. R.I.A.M., Kyushu Univ. Japan, 16 (54), pp 239-250 (1968).

70. Kumai, T. and Tasai, F., "On the Wave Exciting Force and Response of Whipping of Ships," Eur. Shipbldg., 19 (4), pp 42-47 (1970).

71. Kumai, T., "Wave-Induced Force Exciting Hull Vibration and Its Response," JSNA-West Japan, No. 44 (Aug 1972).

72. Kumai, T., "On the Three-Dimensional Entrained Water in Vibration of Lewis' Section Cylinder with Finite Length," JSNA-West Japan, No. 50 (Aug 1975).

73. Lamb, H., Hydrodynamics, Cambridge Univ. Press (1895).

74. Landweber, L. and Macagno, M., "Added Mass of Two-Dimensional Forms Oscillating in a Free Surface," J. Ship Res., 1 (3), pp 20-30 (1957).

75. Landweber, L. and Macagno, M., "Added Mass of a Three Parameter Family of Two-Dimensional Forms Oscillating in a Free Surface," J. Ship Res., 2 (4) (1959).

76. Landweber, L. and Macagno, M., "Added Mass of a Rigid Prolate Spheroid Oscillating Horizontally in a Free Surface," J. Ship Res., 3 (4), pp 30-36 (1960).

77. Landweber, L. and Macagno, M., "Added Mass of Two-Dimensional Forms by Conformal Mapping," J. Ship Res., 11 (2), pp 109-116 (1967).

78. Landweber, L., "Vibration of a Flexible Cylinder in a Fluid," J. Ship Res., 11 (3), pp 143-150 (1967).

79. Landweber, L., "Natural Frequencies of a Body of Revolution Vibrating Transversely in a Fluid," J. Ship Res., 15 (2), pp 97-114 (1971).

80. Lazan, B.J., Damping of Materials and Members in Structural Mechanics, Pergamon Press, London (1968).

81. Leibowitz, R.C. and Kennard, E.H., "Theory of Freely Vibrating Non-Uniform Beams, Including Methods of Solution and Application to Ships," David Taylor Model Basin Rep. 1317 (1961).

82. Lewis, F.M., "The Inertia of the Water Surrounding a Vibrating Ship," Trans., Soc. Naval Architects Marine Engr., 37, pp 1-20 (1929).

83. Lewis, F.M., "Propeller-Vibration Forces," Trans., Soc. Naval Architects Marine Engr., 71, pp 293-318 (1963).

84. Lewis, F.M., "Propeller Vibration Forces in Single-Screw Ships," Trans., Soc. Naval Architects Marine Engr., 77, pp 318-334 (1969).

85. Lin, Y.K., Probalistic Theory of Structural Dynamics, McGraw-Hill (1967).

86. Little, R.S. and Lewis, E.V., "A Study of Wave-Induced Bending Moments," Shipping World and Shipbuilder, 165 (3867), pp 357-360.

87. Madsen, N., "Vertikale Skrogsvingninger i Store Tankskibe," Dept. Ocean Engr., Tech. Univ. Denmark (1975).

88. Maeda, Y., "On the Coupled Vibration of the Longitudinal Vibration, Vertical Vibration and the Vibration of Shaft System," 2nd Rep., JSNA-West Japan, No. 44 (Aug 1972).

89. Mathewson, A.W., "Calculation of the Normal Vertical Flexural Modes of Hull Vibration by Digital Process," David Taylor Model Basin Rep. 706 (1950).

90. McGoldrick, R.T. and Russo, V.L., "Hull Vibration Investigation on SS Gopher Mariner," Trans., Soc. Naval Architects Marine Engr., 63, pp 436-475 (1955).

91. McGoldrick, R.T., "Ship Vibration," David Taylor Model Basin Rep. 1451 (1960).

92. Meirovitch, L., Analytical Methods in Vibrations, MacMillan, London (1967).

93. Miśra, Prayag Narayan, "Transverse Vibrations of a Ship Hull in Ideal Fluid, Determined through Variational Methods," J. Ship Res., 18 (3), pp 185-202 (1974).

94. Myklestad, N.O., "A New Method for Calculating Natural Modes of Uncoupled Bending Vibrations of Airplane Wings and Other Types of Beams," J. Aeron. Sci., 11, pp 153-162 (1944).

95. Nering, K. et al, "Theroetische und experimentelle Untersuchungen zur Beeinflussung der Resonanzschwingungen des Schiffskörpers ausgeführt an einer Serie von Kühl- and Transportschiffen," Schiffbauforschung, 13 (1/2), pp 1-13 (1974).

96. Ohtaka, K., Kumai, T., Ushijima, M., and Ohji, M., "On the Horizontal and Torsional Vibration of Ships," JSNA-Japan, 121 (June 1967).

97. Ohtaka, K., Kagawa, K., and Yamamoto, T., "Higher Mode Vertical Vibration of a Giant Tanker," JSNA-Japan, 125 (1969).

98. Ohtaka, K., "Vertical Vibration of Ships Coupled with Bottom Vibration," Mitsubishi Tech. Bull. No. 83 (1973).

99. Oossanen, P. van and Kooy, J. van der, "Vibratory Hull Forces Induced by Cavitating Propellers," Trans. RINA, 115, pp 111-144 (1973).

100. Oosterveld, M.V.C., Verdonk, C., Kooy, J. van der, and Oossanen, P. van der, "Some Propeller Cavitation and Excitation Considerations for Large Tankers," West European Conf. Mar. Tech. Proc., Delft (May 1974).

101. Palm, L., "Ermittlung der Schubsteifigkeit zur Berechnung höherer Eigenfrequenzen und Eigenformen von vertikalen Schiffskörperschwingungen," Schiffbauforschung, 14 (5/6), pp 153-162 (1975).

102. Pohl, K.H., "Die durch eine Schiffschraube auf benachbarten Platten erzeugten periodischen hydrodynamischen Drücke," Schifftechnik, 7 (35), pp 5-18 (1960).

103. Porter, W.R., "Pressure Distributions, Added-Mass and Damping Coefficients for Cylinders Oscillating in a Free Surface," Inst. Engr. Res., Univ. Cal. (1960).

104. Postl, R., "Elastische Schwingungen in der Schiffstechnik," Z. Agnew. Math. Mech., 52, pp T281-T287 (1972).

105. Prohaska, C.W., "Vibrations Verticales du Navire," Bull. de l'Association Technique Maritime et Aéronautique (1947).

106. Reed, F.E., "The Design of Ships to Avoid Propeller-Excited Vibrations," Trans., Soc. Naval Architects Marine Engr., 79, pp 244-280 (1971).

107. Restad, K., Volcy, G.C., Garnier, H., and Masson, J.C., "Investigations on Free and Forced Vibrations of an LNG Tanker with Overlapping Propeller Arrangement," Trans., Soc. Naval Architects Marine Engr., 81, pp 307-347 (1973).

108. Robinson, D.C., "Damping Characteristics of Ships in Vertical Flexure and Considerations in Hull Damping Investigations," David Taylor Model Basin, No. 1876 (Dec 1964).

109. Ruiz-Fornells, R. et al, "Hull Vibrations," Astilleros Espanoles, S.A. Symp. Paper, BSRA Trans. No. 3888 (1976).

110. Schade, H.A., "Effective Breadth of Stiffened Plating," Trans., Soc. Naval Architects Marine Engr., 59, pp 403-430 (1951).

111. Schade, H.A., "Effective Breadth Concept in Ship Structures," Trans., Soc. Naval Architects Marine Engr., 60, pp 410-430 (1953).

112. Schadlofsky, E., "The Calculation and Measurement of Elastic Natural Frequencies of Ship Hulls," Schiffbautechnische Gesellschaft, 13 (1932).

113. Schlick, O., "On the Vibration of Steam Vessels," Trans. INA (1884).

114. Schmitz, K-P, "Zum Problem der erzwungenen gekoppelten horizontal - torsionsschwingungen des Schiffskörpers," Schiffbauforschung, 13 (1/2), pp 14-19 (1974).

115. Sellers, M.L. and Kline, R.G., "Some Aspects of Ship Stiffness," Trans., Soc. Naval Architects Marine Engr., 75, pp 268-288 (1967).

116. Senjanović, I. and Skaar, K.T., "Problems of Coupling between Ship Hull and Substructure Vibration," HANSA, 112 (20), pp 1574-1578 (1975).

117. Senjanović, I. and Skaar, K.T., "Problems of Ship Vibration Present Solutions and Further Investigations," Trans., Soc. Naval Architects Marine Engr., Sp. Mtg. (June 1976).

118. Sezawa, K. and Watanabe, W., "Damping Forces in Vibration of a Ship," JSNA-Japan, 59 (1936).

119. Shioiri, J. and Tsakonas, S., "Three-Dimensional Approach to the Gust Problem for a Screw-Propeller," J. Ship Res., 7 (4), pp 29-53 (1964).

120. Smith, C.S., "Buckling and Vibration of a Ships Vee- Bottom Structure," Trans. RINA, 116, pp 261-274 (1974).

121. Sparenberg, J.A., "Application of Lifting Surface Theory to Ship Screws," Koninkl. Ned. Akad. Wetenschap, Proc. Amsterdam, 62, Ser. B (1959).

122. Suetsugu, I. and Fujii, K., "The Effect of the Bottom Vibration on the Hull Natural Frequencies," Intl. Shipbldg. Prog., 10 (109), pp 351-364 (1963).

123. Tasai, F., "Formula for Calculating Hydrodynamic Force of a Cylinder Heaving on a Free Surface (n-Parameter Family)," Note Rep. RIAM, Kyushu Univ. Japan, 8 (31), pp 71-74 (1960).

124. Taylor, J.L., "Some Hydrodynamical Inertia Coefficients," Phil. Mag., 9 (1930).

125. Taylor, J.L., "Vibration of Ships," Trans. INA (1930).

126. Todd, F.H., "Some Measurements of Ship Vibration," Trans. North East Coast Instn. Engr. Shipbldg., 48, pp 65-88 (1931-32).

127. Todd, F.H., Ship Hull Vibration, Edw. Arnold, London (1961).

128. Townsin, R.L., "Virtual Mass Reduction Factors, J'Values for Ship Vibration Calculations Derived from Tests with Beams Including Ellipsoids and Ship Models," Trans. RINA, 111, pp 385-397 (1969).

129. Tsakonas, S., Breslin, J.P., and Miller, M., "Correlation and Application of an Unsteady Flow Theory for Propeller Forces," Trans., Soc. Naval Architects Marine Engr., 75, pp 158-180 (1967).

130. Tsakonas, S., Jacobs, W.R., and Rank, P.H., "Unsteady Propeller Lifting-Surface Theory with Finite Number of Chordwise Modes," J. Ship Res., 12 (1), pp 14-45 (1968).

131. Tsakonas, S. and Jacobs, W.R., "Propeller Loading Distributions," J. Ship Res., 13 (4), pp 237-257 (1969).

132. Tsakonas, S. et al, "Documentation of a Computer Program for the Pressure Distribution, Forces and Moments on Ship Propellers in Hull Waves," Stevens Inst. Tech., Rep. SIT-DL-76-1863 (1976).

133. Verbrugh, P.J., "Unsteady Lifting Surface Theory for Ship Screws," Netherlands Ship Model Basin Rep. 68-036-AH, 62 (5) (1968).

134. Vorus, W.S., "A Method for Analyzing the Propeller-Induced Vibratory Forces Acting on the Surface of a Ship Stern," Trans., Soc. Naval Architects Marine Engr., 82, pp 186-198 (1974).

135. Ward, G. and Willshare, G.T., "Propeller-Excited Vibration with Particular Reference to Full-Scale Measurements," RINA Sp. Mtg., Paper No. 4 (1975).

136. Wereldsma, R., "Tendencies of Marine Propeller Shaft Excitations," Intl. Shipbldg. Prog., 19 (218), pp 328-332 (1972).

137. Wereldsma, R. and Moeyes, G., "Wave and Structural Load Experiments for Elastic Ships," Eleventh Symposium Naval Hydrodynamics, Dept. Mech. Engr., Univ. College London, pp VI.3-VI.15 (Mar-Apr 1976).

138. Yamakoshi, M. and Ohnuma, S., "On the Coupling of Hull Vibration and Bottom Vibration of Ships," JSNA-Japan, 118 (Dec 1965).

INA: Institution of Naval Architects, London

RINA: Royal Institution of Naval Architects

JSNA: Journal of the Society of Naval Architects, Tokyo

RIAM: Research Institute for Applied Mechanics

BSRA: British Ship Research Associates

BOOK REVIEWS

INTERNATIONAL DICTIONARIES OF SCIENCE AND TECHNOLOGY - SOUND

Edited by R. W. B. Stephens, Ph.D.
Halsted Press (Division of John Wiley and Sons, New York)

This is the first in a new series of dictionaries on modern scientific terminology; the series is being published in eight languages. The Editor is a Senior Research Fellow at Chelsea College, University of London. The ten specialist editors are on the faculty of universities in England. British spellings are used; "American variants" are given as synonyms.

The dictionary contains more than 3,500 definitions relating to sound technology. The indices, which refer the reader to the English definitions, are: Deutsches Verzeichnis, Index Francais, Indice Italiano, Nederlands Index, Indice Português, Russian Index, and Indice Español.

Two examples will show how this dictionary is used. The word acceleration is followed by the number 0013. The word definition is followed by the formula for acceleration; the unit is metre per second per second (ms^{-2}). The other language equivalents are given as: German - Beschleunigung (f) Geschwindigkeitsänderung (f); French - accélération (f); Italian - accelerazione (f); Dutch - versnelling; Portuguese - aceleração (f); Spanish - aceleración; and Russian - YCKOPEHИE (cp). The word reaction in the French index refers the reader to the numbers 1148 and 1149; both are English definitions of the word feedback.

There are many illustrations, diagrams, graphs, and formulas in the definitions section; standard international units are used.

This dictionary is the work of scientists and technologists from eight nations. The definitions link concepts of many different fields of science and technology: general physics, music, anatomy, electronics, psychology, sound recording and reproduction, and, of course, acoustics (87 terms beginning with "acoustic" or "acousto" are included). Colloquial terms are also given; words used to describe sounds, for example, include buzz, bang, cheep, chirp, click, clang, clatter, crackle, tinkle, din, tick, and squeak.

Many of the definitions are fairly compatible with those in the International Standards "Vibration and Shock - Vocabulary" (ISO 2041); in some instances the definitions are stated differently. This dictionary is a comprehensive compilation of definitions pertaining to sound and related technologies. It will be helpful to a wide range of professionals including architects, broadcasters, engineers, industrialists, importers and exporters, physicists, musicians, clinicians, translators, interpreters, and those preparing technical standards for domestic and international use.

D. C. Kennard, Jr.
3830 Incochee Trail
Traverse City, MI 49684

FRACTURE MECHANICS OF COMPOSITES
ASTM STP 593

The articles in this ASTM Special Technical Publication were presented at a symposium in September, 1974. The book contains three major sections: theoretical investigations, experimental investigations, and crack arrestment in composite structures.

Three articles on theoretical analysis deal with three-dimensional crack analysis in laminar composites. Hilton and Sih develop an approximate three-dimensional crack solution based upon the variational principle of minimum complementary potential energy. Each lamina is assumed to be isotropic and homogeneous; the elastic properties are allowed to vary from layer to layer. Results of this analysis have shown the through-the-thickness variation of the near-tip stress field and the possibility of using an average stress intensity factor to predict the extension of cracks in an individual layer of a laminate. Two articles by Wang, Mandell, and McGarry deal with three-dimensional finite-element analysis of laminar composites. The layers in the cross-plied laminates are assumed to be anisotropic. Extensive numerical results identify the type of singularity of the inplane stress components and the variation of the interlaminar shear and normal stresses. The analyses are extended to the case of crack tip damage consisting of subcracks parallel to the fibers of each layer in a cross-plied laminate. The results indicate that the fundamental concept of a zone of relaxed stresses near the main crack tip, surrounded by an undisturbed singular stress field, is preserved. The important but difficult three-dimensional crack problem in composites is discussed. Two papers, one by Atluri, Kobayashi and Nakagaki and the other by Konish analyze the stress intensity factor for cracks in laminates modeled as homogeneous solids. The effects of crack geometry and material anisotropy on stress intensity factors in composite materials are demonstrated, and a much needed theoretical basis for valid reduction of experimental data is given. A paper by Nuismer and Whitney presents a fracture theory that can be used to explain the fracture behavior of laminates containing both circular holes and cracks. Two analytical models proposed to explain the hole size effect do not use linear elastic fracture mechanics. An extensive experimental program was conducted to assess the accuracy of the models with changes in material systems, fiber orientations, and notch shape and size.

The first paper in the section on experiments is by Slepetz and Carlson; the fracture toughness of S-glass/epoxy and graphite/epoxy composites was investigated. A paper by Adsit and Waszczak examines the fracture of boron/aluminum containing holes and notches. The fracture data are reduced with conventional linear elastic fracture mechanics methods. Brinson, Renieri, and Herakovick studied the rate and time-dependent failure of two structural adhesives used in bonding composites; they conducted a test program to ascertain stress-strain, strain-rate, time, yield, and failure behavior. Analytical predictions agreed well with experimental stress-strain and strain-rate data.

The third section addresses the problem of degree of damage tolerance in composite structures. Bhatia and Verette evaluated the potential of the buffer strip concept for providing fracture control in graphite/epoxy laminated composites panels. Sendeckyj derived crack arrestment criteria for composite panels containing buffer strips. The criteria, which can be used to size the buffer strips to arrest cracks of given length, are in good agreement with experimental data.

Overall, this book provides a balanced view of developments pertaining to theoretical and experimental fracture mechanics. The book should appeal to researchers and practicing engineers who work with composites. There are very few typographical errors, and the editor is to be commended.

Tsu-Wei Chou
Mechanical and Aerospace Engineering
University of Deleware
Newark, DE 19711

NEWS BRIEFS

news on current and Future Shock and Vibration activities and events

BOOK ANNOUNCEMENT

STRUCTURAL MECHANICS SOFTWARE SERIES VOLUME I

Edited by
N. Perrone and W. Pilkey

This book, written by leading authorities, provides user documentation for readily available structural analysis and design computer programs, as well as reviewing and assessing programs which are available on large, mini, and desk computers. Seven programs are documented in this volume, and they are all available by remote terminal access on national computer networks. Also, programs in the following areas are reviewed: computer-aided building design, symbolic and algebraic manipulation languages, curved girder bridge systems, floor analysis and design, three-dimensional dynamic motion simulators.

Encompassing all aspects of solid and structural mechanics, technical area coverage for this series includes biomechanics, structural interaction with other media such as fluids or soil, analysis and design, soils, fracture, rotor dynamics, fatigue, creep, dynamics, statics, etc. All pertinent branches of engineering which in some way treat the structural mechanics discipline are to be included in these volumes: civil, mechanical, aerospace, industrial, nuclear, marine, etc.

This first folume is available from the University Press of Virginia, Box 3608, University Station, Charlottesville, VA 22903.

ACOUSTICAL SOCIETY OF AMERICA SHOCK AND VIBRATION COMMITTEE

CALL FOR ABSTRACTS

The Shock and Vibration Committee of the Acoustical Society of America is planning a symposium on the "Experimental Simulation of Earthquake Response" for the meeting of the Society in Miami Beach, 13 - 16 December 1977.

The purpose of the symposium is to review and assess the state-of-the-art in the seismic testing of mechanical and electrical equipment. Contributions which advance the state-of-the-art will also be considered.

Please forward the abstract to:

Prof. F. C. Nelson
Dept. of Mech. Engineering
Tufts University
Medford, MA 02155

Deadline for receipt of abstracts is September 6, 1977.

SHORT COURSES

JULY

EIGHTH ANNUAL INDUSTRIAL AND PRODUCT NOISE CONTROL INSTITUTE

Dates: July 11 - 15, 1977
Place: Union College, Schenectady, New York
Objective: The basic nature of sound and noise control, including noise criteria, airborne sound distribution, vibration control and noise signature analysis will be covered. Noise measurement equipment will also be also be studied.

Contact: Graduate Studies and Continuing Education, Wells House - 1 Union Ave., Union College, Schenectady, NY 12308, Tele (518) 370-6288

THIRD INTERNATIONAL OCEAN ENGINEERING AND MANAGEMENT COURSE

Dates: July 11 - 22, 1977
Place: UCLA Campus, Los Angeles, California
Objective: To provide an annual educational forum for technology transfer between engineering and management working in the field of ocean technology development.

Contact: Ocean Engineering and Management Course, 6266 Boelter Hall, UCLA Extension, Los Angeles, CA 90024, Tele (213) 825-3858

DYNAMIC ANALYSIS OF OFFSHORE STRUCTURES

Dates: July 18 - 22, 1977
Place: UCLA Campus, Los Angeles, California
Objective: This course will stress practical techniques of dynamic (random data) analysis and structural measurements for determining dynamic properties of offshore structures, such as platforms, caisons, risers, etc. These methods are based upon applications of spectral density, frequency response, coherence functions and other statistical quantities which can be computed from available measured data.

Contact: Ocean Engineering and Management Course, 6266 Boelter Hall, UCLA Extension, Los Angeles, CA 90024, Tele (213) 825-3858

INSTRUMENTATION FOR MECHANICAL ANALYSIS

Dates: July 25 - 29, 1977
Place: University of Michigan, Ann Arbor, MI
Objective: Emphasis is on the use of instruments by non-electrical engineers to analyze systems. Attendees will use a wide range of transducers and associated instrumentation. Morning lectures are devoted to theory and afternoons to various applications in the laboratory. Previous instrumentation experience is not required.

Contact: Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109

AUGUST

NOISE CONTROL IN ENGINEERING

Dates: August 8 - 12, 1977
Place: University of Michigan, Ann Arbor, MI
Objective: Risk of hearing damage from factory noise (e.g., OSHA regulations) and excessive product noise (e.g., EPA regulations) constitute serious concerns for industry. This course provides engineers and managers with comprehensive knowledge of noise control engineering and criteria for application to practical problems.

Contact: Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109

STATIC AND DYNAMIC FINITE ELEMENT ANALYSIS WITH COMPUTER WORKSHOP

Dates: August 8 - 12, 1977
Place: MIT, Cambridge, Massachusetts
Objective: *The objective in this program is to present* the essential details of selecting an appropriate finite element model, analyzing the model, and interpreting the results. This is achieved by a coordinated set of lectures and a computer workshop.

Contact: Office of the Summer Session, RM E19-356, Massachusetts Institute of Technology, Cambridge, MA 02139, Tele (617) 253-2101

IMPEDANCE AND DYNAMIC ANALYSIS OF STRUCTURES

Dates: August 15 - 19, 1977
Place: State College, PA
Objective: To present measurement and analysis techniques by which impedance, transfer, and impulse functions are used directly in prediction of structural response to ground motion or pressure loading, in fluid-structure interaction, in identifying modal properties of structures, and in arriving at finite element models.

Contact: Dr. V.H. Neubert, 133 Hammond Bldg., The Pennsylvania State University, University Park, PA 16802, Tele (814) 865-6161

THE SCIENTIFIC AND MATHEMATICAL FOUNDATIONS OF ENGINEERING ACOUSTICS

Dates: August 15 - 26, 1977
Place: MIT, Cambridge, Massachusetts
Objective: This program is a specially developed course of study which is based on two regular MIT subjects (one graduate level and one undergraduate level) on vibration and sound in the Mechanical Engineering Department. The program emphasizes those parts of acoustics -- the vibration of resonators, properties of waves in structures and air -- the generation of sound and its propagation that are important in a variety of fields of application. The mathematical procedures that have been found useful in the processing of data are also studied.

Contact: Richard H. Lyon, Massachusetts Institute of Technology, Rm. 3-366, Dept. of Mech. Engrg., Cambridge, MA 02139

SEPTEMBER

CORRELATION AND COHERENCE ANALYSIS FOR ACOUSTICS AND VIBRATION PROBLEMS

Dates: August 29 - September 2, 1977
Place: UCLA, Los Angeles, California
Objective: This course covers the latest practical techniques of correlation and coherence analysis -- ordinary, multiple, and partial -- for solving acoustics and vibration problems in physical systems.

Contact: Continuing Education in Engineering and Mathematics, Short Courses, 6266 Boelter Hall, UCLA Extension, Los Angeles, CA 90024, Tele (213) 825-1047

FINITE ELEMENT ANALYSIS WORKSHOP

Dates: September 29 & 30, 1977
Place: Chicago, Illinois
Objective: This course covers the finite element modeling of machines and structures. The theory and practice of the finite element method will be discussed along with pertinent examples and case histories. Participants will be able to work their own problems.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, Suite 206, 101 W. 55th St., Clarendon Hills, IL 60514, Tele (312) 654-2254/654-2053

STANDARDS REVIEW

INTERNATIONAL STANDARDS ORGANIZATION TECHNICAL COMMITTEE 108

Excerpts of reports from ISO/TC 108/TAG 26 and S2/39 on Mechanical Vibration and Shock are given below. The entire reports are available from the ASA Standards Secretariat, Acoustical Society of America, 335 East 45th Street, New York, NY 10017.

Reports of the meetings of TC 108 SC1, and the working groups held in London in September, 1976, were presented at the meeting of Standards Committee S2, which was held in conjunction with the Shock and Vibration Symposium, in Albuquerque, New Mexico, in October, 1976. Work begun in London has been continued (see the January, 1977, issue of the Shock and Vibration Digest.)

ISO 3945-1977 Measurement and Evaluation of Vibration Severity of Large Rotating Machines in Situ, Operating at Speeds from 10-200 rps, prepared by TC 108/SC2, was published by the ISO in February 1977; copies are available from ANSI. This ISO standard is now being considered as a possible ANSI standard. TC 108 letter ballots have been issued on various new items proposed at the London meetings. A document on description and evaluation of scales for measuring centers of gravity of free aerospace bodies will be circulated to SC1/WG4.

The ISO Central Secretariat communicated with TC 108 in September, 1976, with respect to a proposal by the European Shock Absorber Manufacturers' Association to enter the following into the work of ISO:

- recommendation for a performance test specification for an "on-car" vehicle suspension testing system
- dimensional standards for shock absorbers

This subject is of interest in the U.S. -- notably within SAE. The ISO Central Secretariat wanted the opinion of TC 108 because the Committee, as well as TC 22 (Road Vehicles), is involved in such work. The TC 108 Secretariat responded in December that, if TC 22 and other concerned approved, TC 108 would assign the proposal to SC2/wg4 Measurement and Evaluation of Vibration and Shock in Land Vehicles. The working group would maintain liaison with TC 22. The Central Secretariat favored setting up a working group within TC 108 in a short time. When TC 22 has formally agreed to this proposal, therefore, the TC 108 Secretariat will circulate a letter ballot on the proposed assignment of the work.

Responsibility for the Secretariat of ISO/TC 108/SC3 has been officially accepted by Denmark. The first meeting since November, 1974, is scheduled for Copenhagen in September, 1977. The next meeting of ISO/TC 108/SC4 will also be held in September in Vienna. The next meeting of TC 108, SC1, SC2, and their respective working groups, is scheduled for September, 1978, in West Berlin.

AMERICAN NATIONAL STANDARDS COMMITTEE S2

A meeting of Standards Committee S2, Mechanical Shock and Vibration, is scheduled for June, 1977, at State College, PA. The fall meeting will again be held in conjunction with the Shock and Vibration Symposium, which is scheduled from October 19-21, 1977, at Huntsville, Alabama.

The revision of **S2.4-1960 (ANSI S2.4/ASA STD.8-1976) Method for Specifying the Characteristics of Auxiliary Equipment for Shock and Vibration Measurements** was approved by ANSI and published by the Acoustical Society. Copies are available from the Standards Secretariat of the Acoustical Society. **ISO/TC 108/SC4 N 16 Vibration and Shock Limits for Occupants in Buildings** was submitted by S3-39 (S2) on Vibration Levels to the U.S. for vote on whether it should be approved for circulation as a DIS (Draft International Standard) as amendment to ISO 2631-1974. Deadline for recommendations for vote and comments was April 1, 1977.

Draft International Standard ISO/DIS 1683.2 Acoustics-preferred Reference Quantities for Acoustic Levels from S1-22 (S2, S3) Reference Quantities for Acoustical Levels was received in January for vote and announced to S2 and Standards Committees S1 and S3 (S1/103). The deadline for votes was March 15, 1977. A meeting of S2-43 (S1) Testing Electronic Components in High Level Sound Fields will be held in conjunction with the IES meeting. A report will be provided at the June, 1977, meeting of S2.

The negative votes for a document on atmospheric blast effects are presently being considered by S2-54. More members are being recruited for S2-61 Mass Properties of Free Aerospace Bodies working group. (This group is the counterpart of ISO/TC 108/SC1/wg4). A draft standard of Techniques of Machinery Vibration Measurement, prepared by S2-71, was submitted to S2 ballot (LB/S2/40) in March.

S2-76 is working on various documents. Negative votes and comments are being reviewed for the ANSI version of ISO DR2372, **A Basis for Specifying Evaluation Standards for the Vibration of Machines With Operating Speeds From 10-200 rps.** The document was ready for publication in May. ISO/TC 108/SC2/wg1 is preparing a recommendation to ISO to include **Shaft-Vibration Measurements for Monitoring of Turbomachines** in ISO DR2372. Panel S2-76 was given this responsibility in September, 1975. The document will be submitted to TC 108 at the Berlin meeting in 1978.

S2-76 is presently formulating a plan for developing future documents on Machinery Vibration. This plan, which will be submitted to TC 108 during the Berlin meeting, will consider rigid and flexible rotors, shaft and bearing measurements, machinery with and without flexible mounts, various speed ranges, etc.

ISO 3945-1977, Mechanical Vibration of Large Rotating Machines With Speeds, Range from 10 to 200 rev/sec - Measurement and Evaluations of Vibration Severity in Site was received in March, 1977. S2-76 will submit this standard to S2 for vote as an ANSI/ASA standard. **Draft ANSI/ASA 24-197X (S2) Techniques of Machinery Vibration Measurement** was received in March. S2-76 recommends that S2 approve it. **ISO/TC 108/SC1/wg4, Mass Properties of Free Aerospace Bodies** was also received in March. S2-76 sent its comments to D.G. Stadelbauer.

An initial report of **S2-79 Specifying Digital Analyzers Used in Conjunction with Shock and Vibration Measurements** is expected at the June meeting of S2. A ballot for approving the withdrawal of **S2.1-1961 Specifications for the Design, Construction and Operation of Variable Duration, Medium-Impact Shock-Testing Machine for Lightweight Equipment** closed in early May. The proposed revision of **ANSI Std. Y.10.11-1953 Letter Symbols and Abbreviations for Acoustics (Fifth Draft),** which will be submitted to letter ballot of ANSI Committees Y1 (Abbreviations) and Y10 (Letter Symbols), was announced to S2, and S3 in April.

Avril Brenig
ASA Standards Manager

ABSTRACT CATEGORIES

ANALYSIS AND DESIGN

Analogs and Analog Computation
Analytical Methods
Dynamic Programming
Impedance Methods
Integral Transforms
Nonlinear Analysis
Numerical Analysis
Optimization Techniques
Perturbation Methods
Stability Analysis
Statistical Methods
Variational Methods
Finite Element Modeling
Modeling
Digital Simulation
Parameter Identification
Design Information
Design Techniques
Criteria, Standards, and Specifications
Surveys and Bibliographies
Tutorial
Modal Analysis and Synthesis

COMPUTER PROGRAMS

General
Natural Frequency
Random Response
Stability
Steady State Response
Transient Response

ENVIRONMENTS

Acoustic
Periodic
Random
Seismic
Shock
General Weapon
Transportation

PHENOMENOLOGY

Composite
Damping
Elastic
Fatigue
Fluid
Inelastic
Soil
Thermoelastic
Viscoelastic

EXPERIMENTATION

Balancing
Data Reduction
Diagnostics
Equipment
Experiment Design
Facilities
Instrumentation
Procedures
Scaling and Modeling
Simulators
Specifications
Techniques
Holography

COMPONENTS

Absorbers
Shafts
Beams, Strings, Rods, Bars
Bearings
Blades
Columns
Controls
Cylinders
Ducts
Frames, Arches
Gears
Isolators
Linkages
Mechanical
Membranes, Films, and Webs
Panels
Pipes and Tubes
Plates and Shells
Rings
Springs
Structural
Tires

SYSTEMS

Absorber
Acoustic Isolation
Noise Reduction
Active Isolation
Aircraft
Artillery
Bioengineering
Bridges
Building
Cabinets
Construction
Electrical
Foundations and Earth
Helicopters
Human
Isolation
Material Handling
Mechanical
Metal Working and Forming
Off-Road Vehicles
Optical
Package
Pressure Vessels
Pumps, Turbines, Fans, Compressors
Rail
Reactors
Reciprocating Machine
Road
Rotors
Satellite
Self-Excited
Ship
Spacecraft
Structural
Transmissions
Turbomachinery
Useful Application

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U. S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

ANALYSIS AND DESIGN

ANALYTICAL METHODS

77-1037

Calculation of Vibration Frequencies by a Hybrid Element Method Based on a Generalized Complementary Energy Principle

K. Brandt
Fachgebiet fuer Leichtbau, Technische Hochschule Darmstadt, West Germany, Intl. J. Numer. Methods Engr., 11 (2), pp 231-246 (1977) 6 figs, 20 refs

Key Words: Complementary energy methods, Natural frequencies, Plates

Based on a generalized complementary energy principle the derivation of the element matrices is presented for calculation of natural frequencies. The degrees-of-freedom are not defined on nodal points but in an abstract way. No restrictions about the number of interpolation functions in the interior and at the boundaries of the element have been introduced. Plate bending problems are used to study the convergence of frequencies depending on the degrees of interpolation functions within the element and on its boundaries and on the number of elements.

77-1038

A Rayleigh-Ritz Approach to the Synthesis of Large Structures with Rotating Flexible Components

L. Meirovitch and A.L. Hale
Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA., In: NASA. Langley Res. Center Advan. in Eng. Sci., Vol. 2, 1976, pp 531-542 (see N77-10265) N77-10280

Key Words: Structural synthesis, Rayleigh-Ritz method

The equations of motion for large structures with rotating flexible components are derived by regarding the structure as an assemblage of substructures. This substructure synthesis approach provides a rational basis for truncating the number of degrees of freedom both of each substructure and of the assembled structure.

77-1039

Sensitivity of Torsional Natural Frequencies

S. Doughty
Dept. of Mech. Engrg., Louisiana Tech. Univ., Ruston, LA 71270, J. Engr. Indus., Trans. ASME, 99 (1), pp 142-143 (Feb 1977) 2 tables, 5 refs

Key Words: Holzer method, Sensitivity analysis, Torsional vibration

The purpose of the present paper is to apply these methods to the torsional vibration problem to obtain a sensitivity analysis for the natural frequencies. Assuming that the Holzer analysis for a particular mode is available, the sensitivity calculations for that natural frequency are sufficiently simple to permit manual computation, or they are readily adapted to computer implementation within a Holzer analysis program.

77-1040

A Study on the Forced Vibration of a Class of Non-Linear Systems with Application to the Duffing Equation. Part I: Analytical Treatment

S. Nocilla
Istituto di Meccanica Razionale, Politecnico di Torino, Meccanica, 11 (1), pp 11-17 (Mar 1976) 3 figs, 24 refs

Key Words: Forced vibration, Duffings differential equations

A new approach for the general study of steady state vibration equations is developed, consisting in the determination of the periodical steady solutions in a suitable parametric form with which the equation is transformed into a nonlinear integral equation. The procedure is developed in detail in the case of the Duffing equation.

77-1041

Ultra-Subharmonic Oscillations in a Nonlinear Vibratory System

T. Yamamoto, K. Yasuda, and I. Nagasaka
Dept. of Engrg., Nagoya Univ., Chikusa-ku, Nagoya, Japan, Bull. JSME, 19 (138), pp 1442-1447 (Dec 1976) 6 figs, 5 refs

Key Words: Vibrating structures, Harmonic balance method, Subharmonic oscillations

For demonstrating the occurrence of ultra-subharmonic oscillations, a theoretical analysis is carried out for a vibratory system with nonlinear spring characteristics of a fourth order polynomial of the displacement. The analysis shows that the ultra-subharmonic oscillations of the order 2/3 and 3/2 are easily induced, that the fourth order term is essential for the occurrence of the oscillations, and that the constant component of the oscillations caused by the fourth order term has a considerable effect on the response curve. By comparing with the analog-computer analysis, the theoretical analysis is shown to be valid.

77-1042

Subharmonic Oscillation of Order 1/3 in Roller Chain. 1st Report. Theoretical Analysis of the System Having Multiple Degrees of Freedom

A. Sueoka and H. Shimizu
Dept. of Engrg., Kyushu University, Higashi-ku, Fukuoka, Japan, Bull. JSME, 19 (138), pp 1448-1457 (Dec 1976) 15 figs, 9 refs

Key Words: Vibrating structures, Chains, Harmonic balance method, Subharmonic oscillations

The subharmonic oscillations of order 1/3 in a roller chain regarded as a system with multiple degrees of freedom are analyzed under the boundary conditions that its one end is fixed and the other end is subject to lateral forced displacement. Such oscillations are excited by the fluctuations of tension, namely of the extension of the chain during vibration. The solutions for these subharmonic oscillations are obtained by applying the harmonic balance method.

OPTIMIZATION TECHNIQUES

77-1043

Optimum Design of Structures with Regard to Their Vibrational Characteristic (1st Report, A General Method of Optimum Design)

H. Yamakawa and A. Okumura
School of Science and Engrg., Waseda Univ., Shinjuku-ku, Tokyo, Japan, Bull. JSME, 19 (138), pp 1458-1466 (Dec 1976) 5 figs, 18 refs

Key Words: Optimum design, Natural frequencies

In this paper, it is intended to establish a general method or algorithm for solving optimum structural design problems, in which natural frequencies are involved in objective functions and/or in conditions of constraints. The proposed method has wide adaptability to various geometries of structures, by making use of the large matrix method or the transfer matrix method for vibration analysis, after discretizing structures by finite-element idealization.

77-1044

Optimal Structural Design Under Dynamic Loads

T.T. Feng, J.S. Arora, and E.J. Haug, Jr.
Div. of Materials Engrg., College of Engrg., The Univ. of Iowa, Iowa City, IA, Intl. J. Numer. Methods Engr., 11 (1), pp 39-52 (1977) 5 figs, 16 refs

Key Words: Minimum weight design, Optimum design, Framed structures, Dynamic structural response

This paper presents an algorithm for optimal design of elastic structures, subjected to dynamic loads. Finite element, modal analysis and a generalized steepest descent method are employed in developing a computational algorithm. Structural weight is minimized subject to constraints on displacement, stress, structural frequency, and member size. Optimum results for several example problems are presented and compared with those available in the literature.

77-1045

The Use of a Random Algorithm for Dynamic Optimization of Mechanisms

B.Z. Sandler
Dept. of Mechanical Engrg., Ben Gurion Univ. of the Negev, Beer Sheva, Israel, J. Engr. Indus., Trans. ASME, 99 (1), pp 153-156 (Feb 1977) 3 figs, 1 table, 6 refs

Key Words: Optimization, Gears, Mechanisms

This paper describes the following two kinds of dynamic optimization problems applied to mechanisms and their solution by using the spectral theory of random processes. Parameters are chosen for a three-mass vibrating system which will insure the minimum vibration of the most important element. The possibility is envisioned of achieving output motion with minimal errors in a gearing mechanism, without increasing the accuracy of the wheels. It is suggested to achieve this effect by the choice of optimal teeth number combination. A randomized optimization algorithm is considered for these aims.

PERTURBATION METHODS

77-1046

Nonlinear Periodic Waves

L. Ting

Courant Inst. of Mathematical Sciences, New York Univ., NY, *In*: NASA. Langley Res. Center Advan. in Eng. Sci., Vol. 3, 1976, pp 837-850 (see N77-10305)

N77-10307

Key Words: Nonlinear analysis, Perturbation theory

Systematic perturbation procedures for the analysis of nonlinear problems are reviewed. The cases when the multiplicity of an eigenvalue is finite or infinite are treated for self-sustained and forced oscillations. The possibility of the formation of shock waves is discussed. Applications to acoustic problems are presented.

STABILITY ANALYSIS

77-1047

Stability Criterion for Stick-Slip Motion Using a Discontinuous Dynamic Friction Model

G. Cockerham and G.R. Symmons

Dept. of Mechanical and Production Engrg., Sheffield Polytechnic, Sheffield, UK, Wear, 40 (1), pp 113-120 (Oct 1976) 7 figs, 9 refs

Key Words: Stick-slip response, Stability

An analysis of stick-slip stability is presented using a discontinuous friction model which consists of a negative damping action for the slip acceleration phase and a constant frictional resistance for the slip deceleration phase. Limiting conditions for stability due to a positive viscous damping action are defined, where transition from self-generated vibrations to smooth sliding occurs. The implications of the theory are discussed for the design and analysis of equipment subject to such vibrations.

STATISTICAL METHODS

(Also see No. 1231)

77-1048

Response of Linear Dynamic Systems with Random Coefficients

J. Dickerson

South Carolina Univ., Columbia, SC, *In*: NASA. Langley Res. Center, Advan. in Eng. Sci., Vol. 2, 1976, pp 741-745 (see N77-10265)

N77-10298

Key Words: Statistical analysis, Dynamic systems, Random parameters

Numerous models of physical systems contain parameters whose values are not known exactly. The physical and mathematical complexities arising in the prediction of the statistical behavior of such systems are discussed.

FINITE ELEMENT MODELING

77-1049

Finite Element Modeling of Natural Vibration Problems

A.V.K. Murty

Dept. of Aeronautical Engineering, Indian Inst. of Science, Bangalore, India, Shock Vib. Dig., 9 (2), pp 19-37 (Feb 1977) 1 fig, 247 refs

Key Words: Finite element technique, Mathematical models, Lumped parameter method, Transfer matrix method, Eigenvalue problems, Reviews

This is a reivew of finite element modeling techniques including lumped parameter, transfer matrix, finite element displacement, finite element force, hybrid and quadratic eigenvalue methods. Applications of the methods to natural vibration problems are given.

MODELING

77-1050

On Plastic Dynamics of Discrete Structural Models

A.A. Cannarozzi and F. Laudiero
Istituto di Scienza delle Costruzioni, Universita di Bologna, Italy, Meccanica, 11 (1), pp 23-35 (Mar 1976) 4 figs, 51 refs
Sponsored by the National Research Council of Italy

Key Words: Dynamic plasticity, Mathematical models

This paper discusses the dynamic loading of rigid-perfectly plastic structures by adopting a structural model discretized with constant stress finite elements. This assumption together with the hypothesis of small displacements and of a piecewise linear yield surface leads to the formulation of a problem in linear inequalities, which is, implicitly, time discretized. A numerical algorithm for solving the problem is directly derived from the mechanical statements. In the appendix an approximate technique is developed, which takes into account the influence of the strain-hardening and the strain rate sensitivity of material.

CRITERIA, STANDARDS, AND SPECIFICIATIONS

77-1051

Aircraft Noise Certification Requirements Which Ensure Use of Available Noise Control Technology

A.L. Pike
Douglas Aircraft Co., McDonnell Douglas Corp., Long Beach, CA 90846, Noise Control Engr., 7 (3), pp 122-131 (Nov - Dec 1976) 11 figs, 8 refs

Key Words: Aircraft noise, Engine noise, Noise reduction, Regulations

Noise certification concepts which attempt to ensure that a given level of noise control technology is incorporated in all conventional takeoff and landing transport aircraft powered by turbofan engines are presented. The key feature of this approach is isolation of an aircraft's propulsion system as the basic noise source to be controlled.

77-1052

Tire Noise Regulations: Technical and Economic Implications

W.A. Leasure, Jr.
Office of Noise Abatement, Office of the Secretary, Dept. of Transportation, Washington, D.C. 20590, Noise Control Engr., 7 (3), pp 140-147 (Nov - Dec 1976) 6 figs, 2 tables, 16 refs

Key Words: Motor vehicle noise, Trucks, Tires, Noise reduction, Regulations

Although it is possible to abate most of the engine-related noise sources on trucks, tire noise remains an unsolved problem at highway speeds. The operational and design variables affecting tire noise are discussed. Technical and economic factors associated with current tire use practices are investigated.

SURVEYS AND BIBLIOGRAPHIES

(Also see No. 1062)

77-1053

A Review of Shock Response Spectrum

Y. Matsuzaki
National Aerospace Lab., Chofu, Tokyo, Japan, Shock Vib. Dig., 9 (3), pp 3-14 (Mar 1977) 3 figs, 45 refs

Key Words: Shock response spectra, Reviews

The objectives of this paper are to review the principal developments of the shock spectrum technique. Analytical aspects are emphasized. Linear and nonlinear systems are treated separately. Use of the Fourier transform as a descriptor of the shock response is briefly mentioned.

77-1054

Turbine Blading Excitation and Vibration

J.S. Rao
Industrial Tribology, Machine Dynamics and Maintenance Engrg. Center, Indian Inst. of Tech., Delhi, India, Shock Vib. Dig., 9 (3), pp 15-22 (Mar 1977) 87 refs

Key Words: Turbine blades, Vibration excitation, Reviews

This article reviews the literature on blade excitation forces, vibration of blades with large aspect ratio, disk-blade interaction, vibration of blades with small aspect ratio, and experimental methods.

77-1055
A Review of the Literature on the Dynamics of Cam Mechanisms
F.Y. Chen
Dept. of Mech. Engrg., Ohio Univ., Athens, OH 45701, Shock Vib. Dig., 9 (3), pp 23-36 (Mar 1977) 3 figs, 154 refs

Key Words: Cams, Dynamic response, Reviews

This article contains a literature survey of the dynamic aspects of the cam mechanism, including the kinematics of cam profiles, system modeling and analysis, system response, and design methods.

77-1056
Shock and Vibration Instrumentation: Accelerometers
W.S. Mitchell
Harza Engineering Co., Chicago, IL., Shock Vib. Dig., 9 (1), pp 15-18 (Jan 1977) 1 fig, 4 refs

Key Words: Shock measurement, Vibration measurement, Measuring instruments, Accelerometers, Reviews

There have been few recent developments in accelerometer design and usage. Rather, changes have been concerned with refinement of transducer design, signal conditioning equipment, and acceleration measurement applications. Acceleration transducers are available for measuring almost any motion from near D.C. to 100 kHz. Temperature is still a limiting factor in certain measurement situations. Sensitivity, fidelity, and dependability are features of accelerometers now in use.

77-1057
Absorbers and Isolators for Torsional Vibration
J.M. Vance
Dept. of Mech. Engrg., Univ. of Florida, Gainesville, FL 32611, Shock Vib. Dig., 9 (2), pp 3-6 (Feb 1977) 2 figs, 16 refs

Key Words: Vibration absorption (equipment), Vibration isolators, Vibration dampers, Torsional vibration, Reviews

This article describes devices used for reducing torsional vibration in rotating machinery. Consistent definitions are given for absorbers, isolators, and dampers.

COMPUTER PROGRAMS

GENERAL
(Also see Nos. 1133, 1161)

77-1058
Computer Programs: Shock and Vibration Isolation
T.F. Derby
Barry Div., Barry Wright Corp., 700 Pleasant St., Watertown, MA 02172, Shock Vib. Dig., 9 (1), pp 19-26 (Jan 1977) 1 fig, 44 refs

Key Words: Shock isolation, Vibration isolation, Mathematical models, Computer programs

The first part of this review describes commonly encountered shock and vibration isolation problems and the modeling and mathematical techniques used to solve them. The second part reviews available computer programs.

77-1059
FLUSH - A Computer Program for Approximate 3-D Analysis of Soil-Structure Interaction Problems
J. Lysmer, T. Udaka, C. Tsai, and H.B. Seed
Earthquake Engrg. Research Center, California Univ., Richmond, CA 94800, Rept. No. EERC-75-30, 150 pp (Nov 1975)
PB-259 332/5GA

Key Words: Computer programs, Interaction: soil-structure, Earthquake response, Nuclear power plants

This report discusses the general principles of seismic soil-structure interaction by finite element methods and provides the theory and manual for a specific computer code, FLUSH.

77-1060
Computation of Dynamic Loads at Grade Crossings: A User's Manual of the Computer Program
A. Ahmad and R.L. Lytton
Texas Transportation Inst., College Station, TX 77840, Rept. No. FHWA/RD-76-S0511, 68 pp (Jan 1976)
PB-259 673/2GA

Key Words: Computer programs, Railroads, Flexibility methods, Stiffness methods, Damping effects, Inertial forces

This report gives the theoretical background and a description of a computer program, DYMOL, along with its revisions. This program was originally written to calculate the dynamic forces applied normal to a rigid surface by moving traffic. Revisions are made in the program to include the flexibility (stiffness, damping and inertia effect) of the riding surface, and a special subroutine is added to generate typical grade crossing profiles. Input formats, program listing and a glossary of variables are given for the use of the program. Also included with the report are the descriptions of the program's subroutines and functions and method of calculation of dynamic loads along with Maysmeter readings.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 1071, 1092, 1093, 1094, 1116, 1117, 1167, 1168, 1195, 1199, 1203, 1204, 1224)

77-1061

Simple Model for Simulating Traffic Noise Spectra

P.C. Cornillon and M.A. Keane

General Motors Corp., Warren, MI, J. Acoust. Soc. Amer., 61 (3), pp 739-743 (Mar 1977) 9 figs

Key Words: Traffic noise, Mathematical models

A comparatively simple six-parameter model has been developed. It models the underlying power spectra of most vehicular traffic noise samples which have been examined. The six free parameters of the model define a system which can easily be represented in either electronic or digital form. In such a form the system can then be used to generate a time series which has the same underlying, or average, power spectrum as the traffic noise which it represents. It does not however incorporate the characteristics noises of motorcycles, trucks, buses, etc. The model can be used as a laboratory tool for identifying the annoying characteristics of traffic noise or for evaluating proposed automobile and truck noise stnadards. As such it is much more flexible than current methods which use actual traffic noise recordings.

77-1062

Highway Traffic Noise Prediction: A State-of-the-Art Review

J.E. Wesler

S/V, Sound Vib., 11 (2), pp 12-16 (Feb 1977) 5 figs, 15 refs

Key Words: Traffic noise, Noise prediction, Reviews

The ability to predict highway traffic noise levels has become increasingly important in recent years, as concern for environmental noise has grown and noise standards have been established for highway design. This article traces very briefly the historical development of highway traffic noise prediction procedures, and examines, also very briefly, the current state-of-the-knowledge in the various factors necessary to these procedures. Some new, previously unpublished data are included to indicate the validity of several of these factors.

77-1063

Elevated Measurement of Traffic Noise Above an Ideal Reverberant City

S.E. Froseth and R.F. Lambert

Dept. of Electrical Engrg., Univ. of Minnesota, Minneapolis, MN 55455, J. Sound Vib., 50 (3), pp 353-368 (Feb 8, 1977) 7 figs, 10 refs

Key Words: Traffic noise, Noise measurement, Measurement techniques

Aerial noise measurement methods may be well suited to the determination of spatially-averaged traffic noise exposure levels, and could possibly be used as a means of assessing the long-term effectiveness of motor vehicle noise regulations. In this study two theoretical models are developed for some specific aerial measurement situations. Several characteristics of the models are examined. Limited experimental measurements agree well with theoretically predicted results; elevated measured noise levels are nearly proportional to the density of the traffic (in vehicles per unit area) on the city streets.

77-1064

Characteristics of Water Noise Radiated by a Wet/Dry Cooling Tower

A.E. Hribar

Acoustics and Noise Control Research, Westinghouse Electric Corp., USA, Noise Control, Vib. and Insul., pp 26-28 (Jan 1977) 3 figs, 1 table, 3 refs

Key Words: Cooling towers, Noise generation

Measurements were made of the water fall noise of a parallel flow, induced draft wet/dry cooling tower to determine what effect the heat exchangers produced on the radiated noise characteristics of the tower. The results indicate that a wet/dry cooling tower of the configuration studied will have a water fall noise level of about 4 - 8dBA less than a conventional wet design of equal cooling capacity and will have a different sound spectrum.

RANDOM

77-1065

Response of Periodic Structures by the Z-Transform Method

L. Meirovitch and R.C. Engels

Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24060, AIAA J., 15 (2), pp 167-174 (Feb 1977) 4 figs, 10 refs

Key Words: Periodic structures, Random excitation, Laplace transformation

Periodic structures are defined as structures consisting of identical substructures connected to each other in identical manner. The response of periodic structures to harmonic excitation can be described by a matrix difference equation. The solution of the matrix difference equation can be obtained by the Z-transform method and it yields the response to both end conditions and external excitations. The method developed necessitates the eigenvalues of the transfer matrix for a typical substructure, so that the procedure is capable of analyzing a periodic structure with the same computational effort necessary to analyze a single substructure. Added advantage is derived from the fact that the method does not require the eigenvectors of the transfer matrix.

77-1066

Parametric Random Excitation of a Damped Mathieu Oscillator

S.T. Ariaratnam and D.S.F. Tam

Solid Mech. Div., Univ. of Waterloo, Waterloo, Ontario N2L 3GI, Canada, Z. angew Math. Mech., 56, pp 449-452 (1976) 2 figs, 8 refs

(In German)

Key Words: Oscillators, Damped structures, Parametric excitation, Random excitation

The effect of parametric random excitation on the moment stability of a damped Mathieu oscillator is investigated. Conditions for stability of the first and second moments of the response are obtained when the harmonic excitation lies in the neighborhood of twice the natural frequency of the oscillator. It is found that the presence of the additional parametric random excitation can cause either a stabilizing or a destabilizing effect depending on the values of certain parameters of the random excitation.

77-1067

Stationary Response of Oscillators with Non-Linear Damping to Random Excitation

J.B. Roberts

School of Engrg. and Applied Sciences, Univ. of Sussex, Brighton BN1 9QT, UK, J. Sound Vib., 50 (1), pp 145-156 (Jan 8, 1977) 5 figs, 10 refs

Key Words: Oscillators, Nonlinear damping, Random excitation

For oscillators with non-linear damping, excited by white noise, an approximation to the stationary joint density function of the displacement and velocity response is derived. This involves reducing the basic two-dimensional Fokker-Planck equation for the transition density function to a one-dimensional equation relating to the energy envelope of the response. Results obtained from this approximation are compared with other theoretical predictions, and also with digital simulation results, in typical cases.

SEISMIC

(Also see Nos. 1072, 1102, 1137, 1139, 1177, 1178, 1179, 1180, 1181, 1185, 1187, 1215)

77-1068

Nonlinear Transient Dynamic Analysis of Yielding Structures

H. Özdemir

Ph.D. Thesis, University of California, Berkeley, 227 pp, 1976

UM 77-4564

Key Words: Seismic design, Energy absorbers, Mathematical models

In an attempt to describe force-deformation behavior of energy absorbers, three mathematical models are presented, all taking the form of rate-type evolutionary equations and utilizing internal variables. A rate-dependent model derived on the physical basis of plastic deformations, and lends itself naturally to a constant-stiffness approach. The rate-independent model is derived from the rate-dependent model and provides a more accurate representation of the behavior of energy-absorbers; however, its effective implementation requires a variable stiffness approach. The rate-independent equations are then further developed to model the deteriorating absorbing capacity of these devices under continued cycling. A third model is based on the assumption that deterioration is cumulative and results from loading into the plastic range. Comparison of experimental and predicted responses shows that the rate-independent models do provide excellent representations of material behavior.

SHOCK

(Also see Nos. 1053, 1126, 1167, 1172, 1189, 1234)

77-1069

Failure Distributions of Shock Models

G. Gottlieb

Dept. of Statistics, Stanford Univ., CA, Rept. No. TR-181, 35 pp (Oct 18, 1976)

AD-A033 430/0GA

Key Words: Failure analysis, Shock excitation, Mathematical models, Mechanical reliability

This paper, considers a single device shock model. The device experiences shocks from the environment, each of which can render the device inoperable. Conditions of the shock process and of the ability of the device to survive shocks are found so that the time to failure distribution of the device falls into one of the common reliability theory classifications. These results are extended to the case where the shock process can be viewed as continuous.

77-1070

Responses of an Infinite Medium with Cavities to an Impact Load at One of the Cavities

K. Nagaya and Y. Hirano

Dept. of Engrg., Yamagata Univ., Yonezawa, Japan, Bull. JSME, 19 (138), pp 1430-1434 (Dec 1976) 5 figs, 15 refs

Key Words: Wave diffraction, Elastic media, Cavity-containing media, Cavity effect

This paper discusses a problem of a diffraction of plane transient waves in an infinite elastic medium with two infinitely long parallel cylindrical cavities to an impact load. In the analysis, it is assumed that an axially symmetric impact load acts at the interface of one of the cavities which is small enough compared with the others. Variations of a tangential stress around the cavity with time are shown in a numerical example.

77-1071

An Experimental Study of Jet Noise. Part II: Shock Associated Noise

H.K. Tanna

Lockheed-Georgia Co., Marietta, GA 30063, J. Sound Vib., 50 (3), pp 429-444 (Feb 8, 1977) 14 figs, 4 refs

Sponsored by the U.S. Air Force Aero Propulsion Lab. and the U.S. Dept. of Transportation

Key Words: Jet noise, Shock excitation

The characteristics of the sound field of shock-containing under-expanded jet flows are studied by measuring the noise from a convergent nozzle operated over an extensive envelope of supercritical jet operating conditions. The measurements were conducted in an anechoic facility.

77-1072

Seismic Source Functions and Magnitude Determinations for Underground Nuclear Detonations

J.R. Murphy

Computer Sciences Corp., 6565 Arlington Blvd., Falls Church, VA 22046, Bull. Seismol. Soc. Amer., 67 (1), pp 135-158 (Feb 1977) 18 figs, 22 refs

Key Words: Seismic detection, Nuclear explosion detection, Underground explosions

A variety of near-regional, regional, and teleseismic ground-motion data have been used to evaluate proposed models of the nuclear seismic source function for underground detonations in tuff/rhyolite emplacement media.

PHENOMENOLOGY

COMPOSITE

(Also see Nos. 1145, 1146)

77-1073

Impact Response of a Layered Composite Containing a Crack

E.P. Chen
Institute of Fracture and Solid Mechanics, Lehigh Univ., Bethlehem, PA 18015, J. Acoust. Soc. Amer., 61 (3), pp 727-730 (Mar 1977) 5 figs, 9 refs

Key Words: Composites, Cracked media, Shock response

The impact response of a crack in a layered composite which is subjected to antiplane shear deformation is considered in this study. The geometry of the composite consists of a finite layer that is sandwiched between two half-planes made of a different material. The finite layer contains a central crack which is oriented normally to the interfaces. Laplace and Fourier transforms are used to reduce the problem to a pair of dual integral equations. The solution to the dual integral equation is expressed in terms of a Fredholm integral equation of the second kind. Dynamic stress intensity factor is obtained as a function of the material properties, the geometry parameters, and time.

77-1074

Dynamic Stiffness and Damping of Fiber-Reinforced Composite Materials

R.F. Gibson and R. Plunkett
Dept. of Engrg. Science and Mechanics, Engineering Res. Inst., Iowa State Univ., Ames, IA 50011, Shock Vib. Dig., 9 (2), pp 9-17 (Feb 1977) 68 refs

Key Words: Fiber composites, Composite materials, Damping coefficients, Stiffness coefficients, Reviews

This paper reviews recent experimental and analytical efforts to characterize the dynamic mechanical properties of fiber-reinforced composite materials.

77-1075

Dynamic Mechanical Behavior of Fiber-Reinforced Composites: Measurement and Analysis

R.F. Gibson and R. Plunkett
Dept. of Engrg. Science and Mechanics, Engineering Res. Inst., Iowa State Univ., Ames, IA 50011, J. Composite Matl., 10, pp 325-341 (Oct 1976) 8 figs, 23 refs

Key Words: Composite structures, Fiber composites, Internal damping, Stiffness, Flexural vibration, Beams

This paper describes analytical and experimental efforts to find the internal damping and elastic stiffness of E-glass fiber-reinforced epoxy beams under flexural vibration. *Stiffness and damping are expressed in terms of effective* complex moduli. The parameters considered in the study are geometric configuration, vibration frequency, and vibration amplitude.

DAMPING

77-1076

Parameters Affecting the Damping Produced by a Septum-Loaded Fibrous Blanket

T.W. Kozyra
H.L. Blachford, Inc., SAE Paper No. 760659, 21 figs, 4 refs

Key Words: Material damping, Testing techniques

A variety of parameters affecting the damping performance of a septum-loaded fibrous blanket were examined by extending the scope of the widely used "Geiger Thick Plate Test Method." Damping performance of a septum-loaded fibrous blanket system is influenced by the spetum mass, the spacer layer material, and the manner in which the system is adhered. Increasing the septum mass improves the damping performance.

77-1077

Parametric Resonance of 4th Order in a Nonlinear Vibrating System Under the Influence of Frictions

N. Van Dao
Polish Academy of Sciences, Inst. of Fundamental Technological Res., Warszawa, Poland, J. of Technical Physics, 17 (4), pp 435-440 (1976) 1 fig, 2 refs

Key Words: Parametric resonance, Coulomb friction

This paper is concerned with the study of the influence of some kinds of friction on the nonlinear oscillations described by the equation with the cubic term at modulation depth: $\ddot{x} + \omega^2 x + \epsilon(cx+dx^3)\cos\gamma t + \epsilon\alpha x^3 + \epsilon R(x, \dot{x}) = 0$, in the resonant zone of 4th order: $\gamma^2 = 16(\omega^2 - \epsilon\Delta)$, where ϵ, ω, c, d, α are constants, $R(x, \dot{x})$ is a function characterizing the frictions considered.

FLUID

(See No. 1138)

SOIL

(Also see Nos. 1059, 1070)

77-1078

Contact Stresses and Ground Motion Generated by Soil-Structure Interaction

H.L. Wong, J.E. Luco, and M.D. Trifunac

Earthquake Engrg. Research Lab., California Inst. of Tech., Pasadena, CA, Intl. J. Earthquake Engr. Struc. Dynam., 5 (1), pp 67-79 (Jan - Mar 1977) 10 figs, 1 table, 9 refs

Sponsored by the U.S. Geological Survey

Key Words: Interaction: soil-structure, Vibration effects, Forced vibration

A study has been made of the dynamic contact stresses that the foundation of a nine-story reinforced concrete building exerts on the soil during forced vibration tests. The effects of the flexibility of the foundation on the contact stress distribution and on the force-displacement relationship for the foundation have been examined in an attempt at testing several simplifying assumptions commonly used in soil-structure interaction studies. Comparisons of calculated and observed ground displacements induced by soil-structure interaction in the immediate neighborhood of the building have also been presented.

EXPERIMENTATION

DIAGNOSTICS

77-1079

Programmable Pocket Calculator Aids Balancing of Turbomachinery

D.A. Levy

Mech. Engrg. Services, Shell Oil Co., Wood River, IL, Oil and Gas J., 75 (8), pp 64-66 (Feb 21, 1977)

Key Words: Diagnostic techniques, Balancing techniques, Turbomachinery

Rapid, simultaneous two-plane balancing with a vibration analyzer, an in-house constructed balancing stand, and a hand-held calculator is described.

77-1080

Frequency Analysis Using a Minicomputer

D.C. Boch

Naval Academy, Annapolis, MD, Rept. No. USNA-TSPR-75, 87 pp (May 17, 1976)

AD-A032 713/0GA

Key Words: Spectrum analysis, Frequency analyzers, Fast Fourier transforms, Computer programs

The spectral analysis of waveforms, whether these waves are acoustic or electrical in nature, has evolved into an important aspect of quite a wide variety of scientific endeavors. Utilized primarily by the Navy in the study of underwater sound, frequency analysis also finds utility in research on mechanical vibrations, speech, music, et cetera. Real-time capability is necessary for many of these applications. That is, the transformation must be completed within the time interval over which its sampled data is acquired so that spectral plots may be generated on a continuing basis. The basis for a computer-aided frequency analysis scheme is known as a Discrete Fourier Transform, or DFT. The inherent flexibility of a general purpose computer lends itself quite well to the implementation of a high speed adaption of the DFT, called a Fast Fourier Transform or FFT.

77-1081

Optimal Design and Evaluation Criteria for Acoustic Emission Pulse Signature Analysis

J.R. Houghton, M.A. Townsend, and P.F. Packman

Dept. of Mech. Engrg., Tennessee State Univ., Nashville, TN 37209, J. Acoust. Soc. Amer., 61 (3), pp 859-871 (Mar 1977) 12 figs, 13 refs

Key Words: Acoustic signatures, Failure analysis, Diagnostic techniques

Design of pulse-recording systems and evaluation criteria (method of analyzing the pulse signature) are investigated with the objective of defining optimal approaches to pulse signal analysis. A representative situation which this paper addresses is the modeling of acoustic emission pulse analysis as a nondestructive means of failure detection in which pulse

density counting is presently the most common evaluative criterion. The instrumentation is modeled and selected analytical pulses are passed through the system. Two alternatives are considered here: frequency spectrum analysis, and time domain reconstruction of the pulse or pulse train (deconvolution). The pulse recording/analysis problem is modeled, and the various analysis techniques are considered. Within practical constraint optimal system designs are defined.

77-1082

Condition Monitoring of Rolling Element Bearings

P.J. Brown

SPM Instrument Ltd., UK, Noise Control, Vib. and Insul., 8 (2), pp 41-44 (Feb 1977) 5 figs

Key Words: Bearings, Diagnostic techniques, Transducers, Shock Pulse Method

The Shock Pulse Method (SPM) used to monitor the condition of rolling element, operates on the principle of measuring the magnitude of mechanical impact which will occur when damage is present in a bearing and when the bearing surface collides with this damage. Because of the large dynamic range of the Shock Pulse Method, it is possible to monitor the condition of a bearing right the way through its normal operating life, and utilizing various evaluation rules, the plant engineer is able to plan bearing replacement in a very systematic fashion.

77-1083

Vibration - Notes on Some Methods of Measurement

P.W. Still

HBM Division of Carl Schenck Ltd., UK, Noise Control, Vib. and Insul., 8 (2), pp 52-54 (Feb 1977) 7 figs

Key Words: Machinery vibration, Vibration measurement, Diagnostic techniques

This article is intended to introduce the plant maintenance engineer or project engineer to a few methods and devices available for the detection and measurement of vibration. Furthermore the content is limited to vibrations caused by machinery and the subsequent effects on both structures and personnel.

77-1084

Equipment, Simple and Sophisticated, Helps Pinpoint Harmful Vibrations

Product Engr. (N.Y.), 48 (3), pp 49-51 (Mar 1977)

Key Words: Diagnostic instrumentation

When vibration threatens product integrity, the cause must be identified. A variety of instrumental sleuths are now available.

77-1085

Electric Motors -- A Mechanical Viewpoint

M.G. Murray, Jr.

Exxon Cehmical Co., Baytown, TX 77520, Hydrocarbon Processing, 56 (2), pp 127-128 (Feb 1977) 1 fig, 5 refs

Key Words: Motors, Failure analysis, Diagnostic techniques

Most electric motor failures are mechanical rather than electrical. Guidelines to minimize vibration in motors are included.

77-1086

Special Treatments of Vibration Sources to Reduce Plant Noise

L.W. Todd

IRD Mechanalysis Ltd., UK, Noise Control, Vib. and Insul., 8 (2), pp 64-72 (Feb 1977) 14 figs

Key Words: Machinery noise, Machinery vibration, Vibration measurement, Vibration control, Diagnostic techniques

This paper presents an approach for dealing with excessive machinery noise through vibration measurement, analysis, and control. Techniques are described for identifying major noise sources along with vibration analysis procedures for identifying specific mechanical defects which cause abnormal or excessive vibration and noise. In addition, suggestions for controlling normal or inherent vibration at the source are outlined along with methods and devices for controlling structure-borne vibration.

77-1087

Proximity Measurement for Engine System Protection and Malfunction Diagnosis

D.E. Bently

Bently Nevada Ltd., UK, Noise Control, Vib. and Insul., 8 (2), pp 37-39 (Feb 1977) 7 figs

Key Words: Diagnostic instrumentation, Transducers

A proximity measurement system for vibration monitoring and machinery malfunction diagnosis is described. The instrument uses the eddy current principle and has a linear voltage output generated by proximator as a function of the gap size, providing the average gap distance from probe tip to the target surface plus vibration excursion level in both frequency and amplitude of the observed motion.

FACILITIES

77-1088

Acoustical Evaluation of the NASA Langley V/STOL Wind Tunnel

I.L. Ver

Bolt Beranek and Newman, Inc., Cambridge, MA, Rept. No. NASA-CR-145087, Rept-2288, 45 pp (1976)

N77-11068

Key Words: Wind tunnels, Test facilities, Acoustic measurement

The results are presented of the acoustical measurements made to supply NASA Langley operating personnel with the acoustical characteristics of the tunnel test section needed for the planning of acoustical measurements and to identify the major noise sources.

77-1089

Simulated Durability Testing of Vehicle Components at National Engineering Laboratory

R. Fraser

Strength of Components and Fatigue Div., National Engrg. Lab., East Kilbride, UK, Closed Loop, 7 (1), pp 18-22 (Feb 1977) 6 figs, 1 table

Key Words: Test facilities, Buses (vehicles), Dynamic tests

To avoid the delays and expense of complete vehicle road testing when assessing vehicle components and subassemblies, British motor manufacturers have employed the testing services of the National Engineering Laboratory (NEL), of the British Department of Industry. The state-of-the-art testing capabilities at NEL have enabled manufacturers to measure, well in advance of actual service experience, the likely behavior and durability of their products.

INSTRUMENTATION

(Also see Nos. 1056, 1080, 1084, 1087, 1171)

77-1090

A Device for Detecting Amplitudes of Vibration of Turbodynamo Blades

V.S. Malyshev

National Lending Library for Science and Technology, Boston Spa, UK, Rept. No. NLL-M-24095-5828.4F, 5 pp (Apr 30, 1975)(Engl. transl. of Russian Patent Appl. 181 6664/18-10)

Availability: British Library Lending Div., Boston Spa, UK

N77-12360

Key Words: Vibration detectors, Turbine blades

A device is described for contactless measurement of the vibrations of turbodynamo wheel blades, and regulation of the signaled level of the detected amplitude. A sensing element output pulse frequency multiplier, a tube, a pulse counter, a comparison circuit, and a setter for the detected amplitude of vibration are connected in series with a single former. The comparison circuit is connected through a trigger to the signaling circuit. The output from a second former is connected to the input of the '0' setting of the second trigger, the setting input of which is connected to the output of the first pulse former, the output to the input of the tube.

77-1091

Calibration of Vibration Transducers

Diesel and Gas Turbine Progress, 43 (3), p 83 (Mar 1977) 2 tables

Key Words: Calibrating, Vibration meters

A shaker system for calibration of vibration transducers is described, which consists of an oscillator-amplifier and a shaker. This system can detect dead bands in faulty transducers as well as calibrate them.

TECHNIQUES

(Also see Nos. 1063, 1076, 1081, 1082, 1190, 1198, 1199)

77-1092

Sound-Power Measurements on Large Machinery Installed Indoors: Two-Surface Method

G.M. Diehl

Ingersoll Rand Co., Phillipsburg, NJ 08865, J. Acoust. Soc. Amer., 61 (2), pp 449-455 (Feb 1977) 6 figs, 11 refs

Key Words: Machinery noise, Noise measurement, Measurement techniques

Sound-power ratings of machinery are becoming more important for a number of reasons. Industrial installations must comply with recently enacted state and local noise control codes, and sound power ratings are needed to predict compliance. In addition to this, the Federal Noise Control Act of 1972 requires labeling of machinery to show maximum noise emission, and this, logically, may be in terms of sound power. There are several ways to determine the sound power of machinery under laboratory conditions, but these procedures are usually not applicable in industrial environments. The two-surface method offers the best practical approach to the problem of calculating sound power ratings of large machinery installed indoors, under actual operating conditions.

77-1093

Qualification Procedures for Free-Field Conditions for Sound-Power Determination of Sound Sources and Methods for the Determination of the Appropriate Environmental Correction

G. Hubner

Siemens AG, Dynamowerk, Laboratorium fuer Maschinengeräusche, Riechssportfeldstrasse 16/805, D-1000 Berlin 19, West Germany, J. Acoust Soc. Amer., 61 (2), pp 456-464 (Feb 1977) 13 figs, 12 refs

Key Words: Machinery noise, Noise measurement, Measurement techniques

For determination of sound power of sources by the "method of enveloping measurement surfaces," the test environment should provide a measurement surface which lies outside the nearfield of the sound source under test and inside a sound field free of undesired sound reflections from room boundaries or reflecting objects near the source. Methods to check the free-field conditions and to qualify a given measurement surface for an actual source under test are the absolute comparison test using a (small) calibrated reference sound source, the relative comparison test using a small test sound source which radiates broadband noise that remains essentially constant during the measurement, and the reverberant test, which requires measurement of reverbation time. Method 3 is only applicable in closed spaces (rooms). Methods 1 and 2 may be used in rooms and outdoors. Methods 1 and 2 require replacing the source under test by the reference sound source or test sound source in the test site. If the source under test cannot be removed, methods 1 and 2 still allow qualification for free-field conditions, with less accuracy. This paper deals mainly with the relative comparison test (method 2) and gives information about the accuracy of the determination of the environmental corrections factor K under different field conditions.

77-1094

Investigation of Procedures for Estimation of Sound Power in the Free Field Above a Reflecting Plane

C.I. Holmer

National Bureau of Standards, Washington, D.C. 20234, J. Acoust. Soc. Amer., 61 (2), pp 465-475 (Feb 1977) 8 figs, 3 tables, 9 refs

Key Words: Machinery noise, Noise measurement, Measurement techniques

This paper presents results from an experimental investigation of the accuracy and precision of various measurement procedures for determining sound-power output of "large" machines in the free field over a reflecting plane out of doors. The purpose of the investigation was to place error bounds on several proposed nearfield measurement procedures, chiefly through the comparison of such properties with sound power levels determined from farfield measurements. The sources used in the study included 17 portable air compressors of various types and sizes powered by internal combustion engines. The data analysis centers on the comparison of sound power levels estimated from measured sound pressure levels on two measurement surfaces, one at 7-m radius (farfield) and a second at 1 m from the surface of the machine (nearfield). Empirical estimates of precision and accuracy are derived for each of several proposed ISO procedures for determination of sound power level.

COMPONENTS

BEAMS, STRINGS, RODS, BARS

(Also see Nos. 1042, 1075)

77-1095

An Investigation of the Effects of High Intensity Impulse Loads on Simply Supported Reinforced Concrete Beams

J.N. Ingram

Ph.D. Thesis, Oklahoma State Univ., 224 pp, 1976 UM 77-5103

Key Words: Beams, Concrete construction, Impact tests

A test program was conducted to evaluate the effect of high intensity impulse loading on reinforced concrete beams. A total of 12 tests were performed on 4 beam types in which the impulse loads were provided by the detonation of a chemical explosive, spherical pentolite, suspended above the test specimens. During the blast tests, measurements were made of the pressure, beam strains, support reactions, and the acceleration of the beam. Following the impulse loading, a test program was conducted to assess structural damage. Static tests were performed to determine the residual strength of the members, which was then related to structural damage. Finally, the measured support reactions and beam strains were compared with strains and reactions predicted by a mathematical model for impulse loaded beams.

77-1096

A Method of Anslysis for Nonlinear Dynamic Response of Prestressed Concrete Beams

R. Lakshmikanthan

Ph.D. Thesis, Oklahoma State Univ., 126 pp, 1976

UM 77-5126

Key Words: Beams, Concrete construction, Mathematical models, Lumped parameter methods, Computer programs

A method of analysis for prestressed concrete beams, under dynamic loads or combined static and dynamic loads, has been developed in this study using a discrete-element mathematical model to represent the actual structure. The method takes into account material nonlinearity by constantly redefining the flexural stiffnesses at selected sections of the structure as deformations occur under transient loads and nonlinear stress-strain behavior takes place. The method employs small deflection theory and single degree of freedom to define the response of the structure. A computer program, which can handle a large variety of parameters, such as material properties, structure shapes and collapse criteria is developed in FORTRAN language.

77-1097

Effect of Self-Excited Frictional Vibration on the Stability of Beams

D. Ottl

Buchfinkweg 43, D-3300 Braunschweig, Bundesrepublik Deutschland, Ing. Arch., 45 (5/6), pp 393-401 (1976) 8 figs, 3 refs

(In German)

Key Words: Beams, Stability, Perturbation theory, Internal damping, External damping

The stability of a bar influenced by frictional forces and frictional torques is investigated by means of a perturbation technique. Examples show that stability depends on the internal and external damping forces, the stiffnesses of the supports and the locations of the frictional forces.

77-1098

A Study on the Forced Vibration of a Timoshenko Beam

B. Zainea

Langley Res. Center, NASA, Langley Station, VA., In: NASA. Langley Res. Center Advan. in Eng. Sci., Vol. 2, 1976, pp 671-685 (see N77-10265)

N77-10292

Key Words: Beams, Forced vibration, Timoshenko theory

By using Galerkin's variational method an approximate solution is developed for a system of two differential equations with linear partial derivatives of the second order. This system of differential equations corresponds to the physical model, known in the literature as the Timoshenko Beam. The results obtained are applied to two particular cases representing respectively: the case of a beam with a rectangular section, with a constant height and a basis with a linear variation; and the case of a beam with a constant basis and a height with cubic variation.

77-1099

Steady-State Response of a Non-Linear System Under Impulsive Periodic Parametric Excitation

C.S. Hsu, W.H. Cheng, and H.C. Yee

Dept. of Mech. Engrg., Univ. of California, Berkeley, CA 94720, J. Sound Vib., 50 (1), pp 95-116 (Jan 8, 1977) 9 figs, 12 refs

Sponsored by the National Science Foundation

Key Words: Bars, Nonlinear systems, Periodic excitation, Parametric excitation, Steady-state response

The non-linear problem of an elastically restrained and damped bar subjected to a periodic impact load is studied in this paper. The possible steady-state response of such a system is examined in a systematical manner. The approach used is to formulate the problem first in terms on nonlinear difference equations and then to investigate the periodic solutions of these equations and their stability character. In this manner the problem is thus linked to the idea of diffeomorphisms in the theory of differentiable dynamics.

77-1100

Optimum Vibrating Beams with Stress and Deflection Constraints

M.P. Kamat
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA., In: NASA. Langley Res. Center Advan. in Eng. Sci., Vol. 2, 1976, pp 509-519 (see N77-10265)
N77-10278

Key Words: Beams, Fundamental frequencies, Bernoulli-Euler method, Timoshenko theory

The fundamental frequency of vibration of an Euler-Bernoulli or a Timoshenko beam of a specified constant volume is maximized subject to the constraint that under a prescribed loading the maximum stress or maximum deflection at any point along the beam axis will not exceed a specified value. In contrast with the inequality constraint which controls the minimum cross-section, the present inequality constraints lead to more meaningful designs. The inequality constraint on stresses is as easily implemented as the minimum cross-section constraint but the inequality constraint on deflection uses a treatment which is an extension of the matrix partitioning technique of prescribing displacements in finite element analysis.

77-1101

Dynamic Behavior of Pretensioned Hawaiian Aggregate Concrete Beams

S.K.L. Fong and H.S. Hamada
Dept. of Civil Engrg., Hawaii Univ., Honolulu, HI 96800, Rept. No. CE76-R2, FHWA/RD-76-S0549, 161 pp (June 1976) (see also PB-259 968)
PB-259 967/8GA

Key Words: Beams, Concretes, Dynamic tests

The purpose of this report is to study the dynamic behavior of prestressed concrete beams made with lightweight Hawaiian aggregate concrete and to determine whether the use of lightweight Hawaiian concrete is advisable for primary structural members. Tests were performed on prestressed concrete beams made with four different types of aggregates -- two lightweight and two normal weight. The beams were tested under cyclic impact loads. The applied load, reaction, deflection, and acceleration-time histories were recorded. This study compares the dynamic response of the lightweight and normal weight prestressed concrete beams. A single-degree of freedom system numerical method for calculation of the dynamic displacement-time history using the static load-deflection relationship is presented.

77-1102

Experimental and Analytical Studies on the Hysteretic Behavior of Reinforced Concrete Rectangular and T-Beams

E.P. Popov
Earthquake Engrg. Res. Center, California Univ., Berkeley, CA, Rept. No. EERC-76-2, 264 pp (May 1976) (see also PB-257 906)
PB-260 843/8GA

Key Words: Beams, Multistory buildings, Reinforced concrete, Earthquake resistant structures, Seismic design

This report describes an experimental and analytical study program carried out for investigating the inelastic behavior of critical regions that may develop in a beam near its connection with the column of a reinforced concrete ductile moment-resisting space frame when subjected to severe earthquake excitations. In the experimental program, a series of nine cantilever beams, representing half-scale models of the lower story girder of a 20-story ductile moment-resisting reinforced concrete office building, was designed according to present seismic codes.

77-1103

Free Vibrations of Open-Section Shear Walls

P.R. Mukherjee and A. Coull
Dept. of Civil Engrg., Univ. of Strathclyde, Glasgow, UK, Intl. J. Earthquake Engr. Struc. Dynam., 5 (1), pp 81-101 (Jan - Mar 1977) 7 figs, 3 tables, 7 refs

Key Words: Beams, Walls, Coupled response, Torsional vibration, Flexural vibration

The coupled torsional-flexural vibration of open-section shear walls, braced by connecting beams at each floor level, is analyzed on the basis of Vlasov's theory of thin-walled beams. The basic dynamic equations and boundary conditions are derived from Hamilton's principle, and a numerical solution obtained by the Ritz-Galerkin method. In addition to the primary torsional and flexural inertias, secondary effects due to rotatory and warping inertia forces have also been taken into account. The method is suitable for both rigid and flexible base conditions. A series of numerical examples is presented in which analytical results are compared with available experimental data, and the effects of secondary inertia forces, base flexibility and connecting beams upon the vibration characteristics of such shear walls are examined for two different structural forms.

77-1104

A Nonlinear Dynamical Theory for Heterogeneous, Anisotropic, Elastic Rods

G.A. Hegemier and S. Nair

Univ. of California, San Diego, La Jolla, CA., AIAA J., 15 (1), pp 8-15 (Jan 1977) 4 figs, 12 refs

Key Words: Rods, Cables (ropes), Stability

A large deformation, small-strain theory is presented for heterogeneous, transverse isotropic, elastic rods with pre-twist. The theory is applicable to practical problems related to the dynamics of cable systems, helicopter blades, space antennae, and similar structures. Two elementary examples are included: reduction of the general theory to particular differential equations governing the planar, steady-state towing of cables, and the steady-state motion of helicopter rotor blades.

77-1105

A Non-Linear Three-Dimensional Dynamic Towed System Model Based on the Finite Element Method

D.E. Calkins

D.Eng. Thesis, Univ. of California, Berkeley, 154 pp, 1976

UM 77-4346

Key Words: Towed systems, Transient response, Mathematical models, Computer programs

A non-linear dynamic model of a towed system is developed using the finite element approach rather than treating the tow-cable as a continuous line structure. The model is three-dimensional in nature and may be used to examine the transient response and frequency response of the towed system during prescribed tow vessel maneuvers, including turns.

77-1106

New Developments in Understanding the Dynamics of Overhead Current Collection Equipment for Electric Railways

A.E.W. Hobbs, R. Illingworth, and A.J. Peters

Dynamics Section, Research and Development Div., British Railways, UK, Closed Loop, 7 (1), pp 3-9 (Feb 1977) 12 figs, 4 refs

Key Words: Railroad cars, Electric vehicles, Catenaries, Transmission lines, Mathematical models

A new approach being pursued by the authors and their colleagues at British Railways Research and Development Division at Derby combines a new, efficient, computational procedure for the prediction of the dynamic behavior of the overhead line and pantograph system with a detailed experimental program aimed at checking the mathematical modeling, stage by stage. Pantograph and overhead line subsystems are described in terms of modal co-ordinates and the dynamic response of each to known excitation is predicted and checked experimentally. Any lack of agreement is then used to refine the subsystem parameters before predictions are made for the pantograph moving under the wire.

BEARINGS

(Also see Nos. 1082, 1206)

77-1107

Tilt Stiffness and Damping Coefficients for Finite Journal Bearings

A. Mukherjee

Dept. of Mech. Engrg., Indian Inst. of Technology, Kharagpur, 721302, India, Wear, 41 (1), pp 87-102 (Jan 1977) 3 figs, 9 refs

Key Words: Journal bearings, Damping coefficients, Stiffness coefficients

An analytical solution of Reynolds' equation for a finite bearing with an inclined journal has been attempted. The tilt stiffness and a bearing coefficient were obtained by analyzing the components of couples exerted by the fluid on the journal for small tilt and tilt rates. A transformation of the coordinate systems was adopted to separate the effects produced by tilt - change in attitude angle and change in eccentricity with length. Expressions for pressure distribution were obtained by solving Reynolds' equation using a perturbation technique together with Fedor-type assumptions. Justification for Fedor-type assumptions is given for length-to-diameter ratios greater than 0.8.

77-1108

The Dynamic Stiffness and Damping of an Externally Pressurized Porous Gas Journal Bearing Under Hybrid Operation

E.P. Gargiulo, Jr.

Ph.D. Thesis, Univ. of Cincinnati, 309 pp, 1976

UM 77-4014

Key Words: Journal bearings, Gas bearings, Mathematical models, Computer programs, Stiffness coefficients, Damping coefficients

A combined theoretical and experimental research program has been completed in which the steady and dynamic characteristics of an externally pressurized porous gas journal bearing were investigated. The objective of this research was to develop a confirmed mathematical model for the dynamic stiffness and damping characteristics of a porous bearing during hybrid operation.

77-1109

Steady State and Dynamic Characteristics of Partial Journal Bearings

B.S. Prabhu

Machine Dynamics Lab., Dept. of Applied Mech., Indian Inst. of Technology, Madras-600036, India,
Wear, 40 (1), pp 1-8 (Oct 1976) 5 figs, 18 refs

Key Words: Journal bearings, Lubrication, Stiffness coefficients, Damping coefficients

The response of the lubricant film of a partial journal bearing to displacements and velocities of its journal for laminar Newtonian flow of the lubricant is presented. The bearing force coefficients (spring and damping coefficients) were evaluated experimentally on a sophisticated test rig, with control over all the essential variables. Test results are presented in non-dimensional form and are applicable to a bearing of 130° arc and with a length-to-diameter ratio of 0.8. Useful design data and a theoretical comparison are given.

77-1110

Whirl Instability of Externally Pressurized Gas-Lubricated Porous Journal Bearings

B.C. Majumdar

Dept. of Mech. Engrg., Indian Inst. of Technology, Kharagpur, 721302, India,
Wear, 40 (2), pp 141-153 (Nov 1976)

Key Words: Journal bearings, Lubrication, Whirling

A study of the whirl instability of externally pressurized gas-lubricated porous journal bearings was made. The theoretical analysis was obtained using a quasi-static assumption. The stability characteristic of a particular journal bearing is given for various supply pressures, design dimensions and feeding parameters. Experimental data confirm the theoretically obtained results.

77-1111

Elastic and Damping Properties of Partial Porous Journal Bearings of Finite Length and Arbitrary Wall Thickness Taking Film Curvature and Slip Flow into Account

V. Kumar

Dept. of Mech. Engrg., Regional Engrg. College, Kurukshetra, Haryana 132119, India,
Wear 40 (3), pp 293-308 (Dec 1976) 2 figs, 12 refs

Key Words: Journal bearings, Lubrication, Elastic properties, Damping values

A self-acting porous journal bearing of finite length has been analyzed in order to obtain the dynamic characteristics when an active film of a homogeneous single-phase liquid lubricant extends over the whole bearing arc span. A new governing lubrication equation which considers slip flow, film curvature and unsteady motion of the journal has been derived and solved analytically to yield results in a closed form for a dynamic load taking into account the curvature of the porous bearing matrix and thus allowing the porous wall thickness to be arbitrary. Closed form results obtained in this way are valid for any arbitrary clearance ratio C/R_1 and wall thickness ratio H/R_1. The dynamic characteristics are evaluated as for impermeable bearings. The pertinent results are fully analytical in nature, simple yet exact and accurate, permitting easy and economical calculation of numerical data over a very wide range of parameters involved.

77-1112

The Influence of Vibration on the Rolling Contact Fatigue Damage of Case-Carburised Steels

R. Ramanathan, V.M. Radhakrishnan, and R. Vasudevan

Metallurgy Dept., Indian Inst. of Technology, Madras 600036, India,
Wear, 40 (3), pp 319-324 (Dec 1976) 10 figs, 5 refs

Key Words: Bearings, Vibration effects, Fatigue tests, Steels

Experiments were carried out with a nutcracker-type test rig to investigate the influence of vibration on the mode of contact fatigue damage of case-carburised steels. Vibration was induced by using an eccentric specimen. Flaking or severe case-crushing-type failure was observed at three different hardness levels. In the absence of vibration, flaking-type failure was observed for the lowest hardness material. Other materials withstood a life of more than 10^7 cycles under the same contact stress conditions.

BLADES

(Also see Nos. 1054, 1090, 1203, 1204)

77-1113

An Experimental Determination of the Unsteady Aerodynamics in a Controlled Oscillating Cascade

S. Fleeter, A. S. Novick, R. E. Riffel, and J. E. Caruthers
Detroit Diesel Allison Div., General Motors Corp., Indianapolis, IN, J. Engr. Power, Trans. ASME, 99 (1), pp 88-96 (Jan 1977) 30 figs, 9 refs

Key Words: Airfoils, Blades, Aerodynamic characteristics

A unique supersonic inlet flow field unsteady cascade experiment is described wherein the time-dependent pressure distribution within an harmonically oscillating airfoil cascade is quantitatively determined. The torsional frequency of oscillation and the interblade phase angle are precisely controlled by means of on-line digital computers. The dynamic data obtained include the chordwise distribution of the unsteady pressure magnitude and its phase lag as referenced to the airfoil motion. Parameters varied include the cascade inlet Mach number, the interblade phase angle, and the reduced frequency. The time-dependent data are correlated with state-of-the-art analytical predictions.

77-1114

Influence of Modeling and Blade Parameters on the Aeroelastic Stability of a Cantilevered Rotor

P. Friedmann
Univ. of California, Los Angeles, Los Angeles, CA 90024, AIAA J., 15 (2), pp 149-158 (Feb 1977) 6 figs, 12 refs

Key Words: Rotor blades, Cantilever plates, Torsional response

A set of equations describing the coupled flap-lag-torsional dynamics of a cantilevered rotor blade in hover is presented. This set of equations is used to evaluate the influence of structural damping, preconing, and offsets on the linearized aeroelastic stability of some representative blade configurations. The sensitivity of the stability boundaries to the assumptions of approximate linear vs exact nonlinear static blade equilibrium position is considered. Finally, results with the distributed torisonal representation of blade properties are compared with those obtained when the root torsional model is used.

77-1115

Dimensional Analysis and Scaling of the Aerodynamic Noise Produced by Idling Circular Saw Blades

R.F. Keltie and W.F. Reiter, Jr.
North Carolina State Univ., Raleigh, NC, ASME Paper No. 76-WA/DE-11

Key Words: Saws, Blades, Noise generation, Dimensional analysis, Scaling

The aerodynamic idle noise produced by circular saw blades is studied. The scaling laws of the aerodynamic noise of the idling saw blades are established through evaluation of the relationship between the dimensionless groups. Slotted disks (similar to saw blades) are used in the investigation. Effects of tip speed, thickness, gullet diameter, depth, and spacing on the noise produced are independently evaluated.

CYLINDERS

77-1116

Acoustodynamics of the Longitudinal Collinear Impact of Finite Elastic Cylinders

G.Y. Matsumoto and W.J. Simpson
Dept. of Mech. Engrg., Pennsylvania State Univ., University Park, PA 16802, J. Engr. Indus., Trans. ASME, 99 (1), pp 144-150 (Feb 1977) 16 figs, 16 refs
Sponsored by the National Science Foundation

Key Words: Impact noise, Noise generation, Cylinders

The acoustodynamics of finite elastic cylinders is examined both experimentally and theoretically to investigate the sources of noise generation associated with longitudinal, collinear impact.

DUCTS

(Also see No. 1129)

77-1117

Non-Linear Propagation of Complex Sound Fields in Rectangular Ducts. Part I: The Self-Excitation Phenomenon

P.G. Vaidya and K.S. Wang
School of Aeronautics and Astronautics, Purdue Univ., Lafayette, IN 47907, J. Sound Vib., 50 (1), Univ., pp 29-42 (Jan 8, 1977) 5 figs, 10 refs
Sponsored by NASA

Key Words: Ducts, Elastic waves, Sound transmission, Self-excited vibrations

Previous studies of acoustic fields in rectangular ducts due to a single higher order mode input have been generalized to the case of multimode inputs at various different frequencies. New phenomena, not to be found in the single input case, have emerged. The existence of "strong interactions" at the first order of the perturbation scheme, and self-excitation of subharmonics.

77-1118

Sound Propagation Through Nonuniform Ducts

A.H. Nayfeh

Virginia Polytechnic Inst. and State Univ., Blacksburg, VA, In: NASA. Langley Res. Center Advan. in Eng. Sci., Vol. 3, 1976, pp 821-833 (see N77-10305)

N77-10306

Key Words: Ducts, Sound waves, Sound transmission

Methods of determining the transmission and attenuation of sound propagating in nonuniform ducts with and without mean flows are discussed. The approaches reviewed include purely numerical techniques, quasi-one-dimensional approximations, solutions for slowly varying cross sections, solutions for weak wall undulations, approximation of the duct by a series of stepped uniform cross sections, variational methods and solutions for the mode envelopes.

77-1119

Features of Sound Propagation Through and Stability of a Finite Shear Layer

S.P. Koutsoyannis

Stanford Univ., Stanford, CA., In: NASA. Langley Res. Center Advan. in Engl. Sci., Vol. 3, 1976, pp 851-860 (see N77-10305)

N77-10308

Key Words: Ducts, Sound waves

The plane wave propagation, the stability and the rectangular duct mode problems of a compressible inviscid linearly sheared parallel, but otherwise homogeneous flow, are shown to be governed by Whittaker's equation. The exact solutions for the perturbation quantities are essentially Whittaker M-functions. A number of known results are obtained as limiting cases of exact solutions. For the compressible finite thickness shear layer it is shown that no resonances and no critical angles exist for all Mach numbers, frequencies and shear layer velocity profile slopes except in the singular case of the vortex sheet.

77-1120

Effects of Mean Flow on Duct Mode Optimum Suppression Rates

R.E. Kraft and W.R. Wells

General Electric Co., Philadelphia, PA., In: NASA. Langley Res. Center Advan. in Eng. Sci., Vol 3, 1976, pp 873-882 (see N77-10305)

N77-10310

Key Words: Ducts, Elastic waves, Sound waves

The nature of the solution to the convected acoustic wave equation and associated boundary conditions for rectangular ducts containing uniform mean flow is examined in terms of the complex mapping between the wall admittance and characteristic mode eigenvalues. It is shown that the Cremer optimum suppression critieria must be modified to account for the effects of flow below certain critical values of the nondimensional frequency parameter of duct height divided by sound wavelength. The implications of these results on the design of low frequency suppressors are considered.

77-1121

Effects of High Subsonic Flow on Sound Propagation in a Variable-Area Duct

A.J. Callegari and M.K. Myers

Courant Inst. of Mathematical Sciences, New York Univ., NY, In: NASA. Langley Res. Center Advan. in Engl. Sci., Vol. 3, 1976, pp 861-872 (see N77-10305)

Sponsored by NASA

N77-10309

Key Words: Ducts, Variable cross section, Sound waves

The propagation of sound in a converging-diverging duct containing a quasi-one-dimensional steady flow with a high subsonic throat Mach number was studied. The behavior of linearized acoustic theory at the throat of the duct was shown to be singular.

77-1122

On the "In-Situ" Control of Acoustic Liner Attenuation

P.D. Dean

Lockheed-Georgia Co., Marietta, GA., J. Engr. Power, Trans. ASME, 99 (1), pp 63-70 (Jan 1977) 12 figs, 1 table, 6 refs

Key Words: Acoustic linings, Acoustic impedance, Ducts

In this paper a concept is presented which enables the attenuation of sound in a lined duct to be controlled via the control of the fundamental liner characteristic (the acoustic impedance). The concept is described and modeled by a semi-empirical analysis. The feasibility is demonstrated by means of measurements of attenuation and local impedance in a small scale flow duct test facility.

77-1123

Inlet Noise Suppressor Design Method Based Upon the Distribution of Acoustic Power with Mode Cutoff Ratio

E.J. Rice
Lewis Research Center, NASA, Cleveland, OH,
In: NASA. Langley Res. Center Advan. in Eng. Sci., Vol. 3, 1976, pp 883-894 (see N77-10305)
N77-10311

Key Words: Acoustic linings, Ducts, Noise reduction

A liner design for noise suppressors with outer wall treatment such as in an engine inlet is presented which potentially circumvents the problems of resolution in modal measurement.

77-1124

Self-Induced Sound Generation by Flow Over Perforated Duct Liners

C.Y. Tsui and G.A. Flandro
Dept. of Mech. Engrg., Univ. of Maryland, College Park, MD 20742, J. Sound Vib., 50 (3), pp 315-331 (Feb 8, 1977) 12 figs, 3 tables, 7 refs

Key Words: Ducts, Acoustic linings, Honeycomb laminates, Hole-containing media, Sound generation

An adverse "singing" phenomenon due to flow over perforated liners in a duct was studied experimentally. The liners consisted of honeycomb structures bonded to and sandwiched between two flat aluminum skins. The inner skin in contact with the flow had holes (perforations) with pitch distances either equal to or different from those of the honeycomb structures, forming, respectively, narrow-band or broadband liners. The shedding of vortices in the flow over these holes induced excitation of acoustic modes within the duct, and under the condition whereby the cut-on frequency of an excited mode coincided with, or was very near to, the shedding frequency a very strong tone corresponding to that particular modal cut-on frequency resulted.

FRAMES, ARCHES

(Also see No. 1044)

77-1125

Nonlinear Static and Dynamic Analysis of Frames

A. Kassimali
Ph.D. Thesis, Univ. of Missouri-Columbia, 169 pp 1976
UM 77-5616

Key Words: Framed structures, Dynamic analysis

With reference to the problem of large deformations and stability of elastic framed structures, computational features of a general Eulerian approach have been examined. Further ramifications of the method (including, in particular, transition from Eulerian to Lagrangian coordinates, and extension of the method to the dynamic case) have also been explored.

77-1126

Large Displacement, Transient Analysis of Space Frames

T. Belytschko, L. Schwer, and M.J. Klein
Dept. of Materials Engrg., Univ. of Illinois at Chicago Circle, Chicago, IL., Intl. J. Numer. Methods Engr., 11 (1), pp 65-84 (1977) 8 figs, 10 refs

Key Words: Transient response, Large amplitudes, Framed structures, Collision research (automotive)

A formulation is presented for the transient analysis of space frames in large displacement, small strain problems. For purposes of treating arbitrarily large rotations, node orientations are described by unit vectors and deformable elements are treated by a co-rotational (rigid-convected) description. Deformable elements may be connected either to nodes directly or through rigid bodies. The equations of motion are integrated by an explicit procedure. Sample results are presented on the snap-through of an arch-type structure and an idealization of a vehicle-barrier impact.

GEARS

77-1127

Dynamic Behavior of Planetary Gear (2nd Report. Displacement of Sun Gear and Ring Gear)

T. Hidaka, Y. Terauchi, and K. Ishioka
Dept. of Engrg., Hiroshima Univ., 3 Sendamachi Hiroshima, Japan, Bull. JSME, 19 (138), pp 1563-1570 (Dec 1976) 17 figs, 8 refs

Key Words: Gears, Dynamic response

In the previous paper, the load distribution of each planet of Stoekicht gear (Type 2K-H) was reported. In the present paper, the displacement of sun and ring gear from their basic positions was measured. Then, the relations among the dynamic loads of sun gear tooth, the load distribution and the displacement of sun and ring gear were studied.

LINKAGES

77-1128

Stiffness of Machine Tool Joints: A Random-Process Approach

T.R. Thomas and R.S. Sayles
Dept. of Mech. Engrg., Teesside Polytechnic, Middlesbrough, UK, J. Engr. Indus., Trans. ASME, 99 (1), pp 250-256 (Feb 1977) 9 figs, 23 refs
Sponsored by the Science Research Council

Key Words: Machine tools, Joints, Stiffness

A random-process surface model of elastically yielding asperities with a gaussian height distribution is proposed to represent the deflection of a machine tool joint. A passband of surface wavelengths taking part in the interaction is derived in terms of workpiece dimensions, material properties, and a plasticity criterion. The necessary moments of the surface power spectrum are computed from profile measurements on a lathe bed, and hence the stiffness of the joint between it and the saddle is calculated. Finally, theoretical predictions of the variation of stiffness with load are compared with published measurements on bolted joints. Good agreement is found for a rectangular planform; for other planforms agreement is reasonable at low preloads.

77-1129

Vibration-Isolating Couplings and Links

T.J.B. Smith
Sound Research Laboratories, Ltd., Noise Control, Vib. and Insul., pp 7-11 (Jan 1977) 6 figs, 2 tables

Key Words: Vibration isolation, Linkages, Ducts, Pipes, Mechanical elements

Virtually any item of a mechanical plant installed in a building, besides interfacing with the structure at its base mountings, will also connect with internal systems and structures, e.g., ducts, pipes, etc. Therefore, springs and other isolators which carry the dead load of the machinery are not sufficient for vibration isolation since all the links between the machine and the area it serves could potentially "short circuit" the vibration-decoupling spring mounts. Consequently, the installed mechanical services must be viewed in their entirety and vibration must be decoupled at all points where transmission of unwanted energy could occur. In the article several standard methods which apply to most conventional systems are described.

MECHANICAL

(Also see No. 1055)

77-1130

Dynamic Response of Elastic Rods Under Parametric Excitations

T.S. Sankar and G. Rajan
Dept. of Mech. Engrg., Concordia Univ., Montreal, Canada, J. Engr. Indus., Trans. ASME, 99 (1), pp 41-45 (Feb 1977) 9 refs
Sponsored by the National Research Council of Canada

Key Words: Mechanical elements, Rods, Linkages, Parametric excitation

The problem of dynamic behavior of parametrically excited *mechanical elements, viz., elastic rods and linkages in mechanisms* and boring bars, is presented using the WKB solutions of a general second-order partial differential equation. The differential equations are solved by using first a plane wave type solution leading to the "regular WKB" solution and then through the solutions of Airy integral type employing the "generalized WKB" method. The analytical techniques are illustrated by considering the lateral vibrations due to an exponentially decaying axial force on a pin-ended rod. It is shown that the regular and generalized WKB solutions are complementary, i.e., where the regular WKB method fails, the generalized WKB solution yields satisfactory results.

77-1131

Design and Analysis of Multilink Flexible Mechanisms with Multiple Clearance Connections

S. Dubowsky and T.N. Gardner
School of Engrg. and Applied Science, Univ. of California, Los Angeles, CA., J. Engr. Indus., Trans. ASME, 99 (1), pp 88-96 (Feb 1977) 13 figs, 4 tables, 35 refs

Key Words: Mechanisms, Elastic properties, Dynamic response

The problem of predicting the dynamic behavior of general planar mechanisms with elastic links and multiple clearance connections is addressed using a perturbation coordinate approach. Particular emphasis is placed on studying the effects of system elasticity on the high internal impact forces generated by the presence of the clearances at high speeds. Two examples of complete systems are considered and their responses are compared to the behavior of relatively simple dynamic models: the object is the development of design guidelines.

77-1132

Mechanisms as Components of Dynamic Systems: A Bond Graph Approach

R.R. Allen and S. Dubowsky

School of Engrg. and Applied Science, Univ. of California, Los Angeles, CA., J. Engr. Indus., Trans. ASME, 99 (1), pp 104-111 (Feb 1977) 9 figs, 17 refs

Key Words: Mechanisms, Bond graph technique

In recent years, bond graphs have been used to analyze complex dynamic systems. In this paper a bond graph study is made of the kinematics and dynamics of a general mechanism treated as a component of a dynamic system. The method is applicable to multiple-loop, multiple degree-of-freedom mechanisms for which the displacement and velocity loop equations are known. A bond graph multiport representing the kinematic relations forms a power-conserving core to which dissipative, inertial, and compliance effects may be added to form a dynamic mechanism model. A constitutive relation suitable for automatic computation is derived in terms of system variables. A numerical example is presented illustrating an application of the technique.

77-1133

Dynamic Simulation of Planar Mechanical Systems with Lubricated Bearing Clearances Using Vector-Network Methods

R.J. Rogers and G.C. Andrews

Dept. of Mech. Engrg., Univ. of New Brunswick, Fredericton, New Brunswick, Canada, J. Engr. Indus., Trans. ASME, 99 (1), pp 131–137 (Feb 1977) 7 figs, 2 tables, 18 refs

Sponsored by the National Research Council of Canada

Key Words: Mechanisms, Computer programs

This paper describes the use of a "self-formulating" computer program, PLANET II, in the simulation of mechanisms with clearances in the revolute connections. The PLANET II program is based on the vector-network method, which is discussed briefly, and requires only the mechanism description to generate the dynamic response. Mathematical models of bearing elements which take into account the effects of clearance, surface compliance, and lubricant have been developed and are included in the program. The various bearing models are described and the results of the simulations of two planar mechanisms are presented. The PLANET II program appears to be a convenient and accurate means of simulating dynamic planar systems.

PANELS

77-1134

Analytical Comparison of Effects of Solid-Friction and Viscous Structural Damping on Panel Flutter

H.J. Cunningham

Langley Research Center, NASA, Langley Station, VA, Rept. No. NASA-TN-D-8263, 36 pp (Nov 1976) N77-12435

Key Words: Flutter, Panels, Coulomb friction, Viscous damping, Galerkin method, Modal analysis

A Galerkin modal analysis is presented that accounts for the effects of both solid friction and viscous structural damping on panel flutter, based on unsteady aerodynamic forces from supersonic potential flow. The eigensolutions are made by complex eigenvalue computer routines.

PIPES AND TUBES

(Also see No. 1129)

77-1135

On Collapse and Flutter Phenomena in Thin Tubes Conveying Fluid

D.S. Weaver and M.P. Paidoussis

Dept. of Mech. Engrg., McMaster Univ., Hamilton, Ontario, Canada, J. Sound Vib., 50 (1), pp 117-132 (Jan 8, 1977) 8 figs, 19 refs

Key Words: Tubes, Fluid-filled containers, Flutter, Collapse

The stability behavior of thin-walled tubes conveying fluid is examined with an emphasis on the effects of tube flattening. Two simplified theoretical models are developed which represent a flattened tube as two parallel flat plates. The first model is in terms of standing waves on finite length plates whereas the second model is in terms of travelling waves on infinitely long, finite width plates. The fluid forces are determined by using potential flow theory. Experiments were conducted with three different tubes, one of which was initially flat. The experimental observations agree with the predictions of the first theoretical model, at least qualitatively.

PLATES AND SHELLS

77-1136

Stability of Reticulated Domes Under Multiple Static and Dynamic Loads

A.O. Abatan
Ph.D. Thesis, Virginia Polytechnic Inst. and State Univ., 239 pp, 1976
UM 77-2759

Key Words: Domes, Stability, Perturbation theory

The primary purpose of this dissertation is to investigate the stability of reticulated domes under multiple static and dynamic loads. Two elastic geometrically nonlinear structural models of a reticulated dome with 21 and 39 degrees of freedom are considered. The nonlinear response of the system to static loads is obtained using nonlinear programming and discrete perturbation techniques. The nonlinear programming technique is used to obtain a starting solution for the discrete perturbation technique and to optimize the choice of the perturbation parameter. Convergence criteria and error estimates to limit errors in a perturbation scheme are developed. A method for selecting a "suitable" perturbation parameter for imperfection sensitive systems is proposed

77-1137

On the Aseismic Design of Liquid Storages

K. Sogabe, T. Shigeta, and H. Shibata
Dept. of Science and Technology, Sophia Univ., Chiyoda-ku, Tokyo, Japan, Bull. JSME, 19 (138), pp 1467-1477 (Dec 1976) 16 figs, 24 refs

Key Words: Seismic design, Storage tanks, Sloshing

The present situation of the aseismic design of liquid storages and its points of issue are pointed out at first. The fundamental concepts of a systematization of the aseismic design of liquid storages are proposed based on these points of issue. The authors carried out a series of experiments and analyses to make clear the fundamental vibrational characteristics of liquid storages. An earthquake response observation of a cylindrical storage model of diameter 4.0 m and response analyses of sloshing of liquid in cylindrical and spherical storages are reported in this paper. The results are summed up into formula and nomogram which are convenient and available for the response calculation of sloshing of liquid in the aseismic design of liquid storages.

77-1138

Response of Partially Filled Elastic Cylindrical Storage Tank Subjected to Arbitrary Lateral Base Excitation

T. Mouzakis
Ph.D. Thesis, Univ. of Massachusetts, 161 pp, 1976
UM 77-6422

Key Words: Storage tanks, Fluid-filled containers, Forced vibration, Computer programs

This dissertation presents an analytic solution for a large ground supported storage tank subjected to arbitrary lateral base excitation. A computer program is developed to obtain the exact solution for the forced vibration of a partially filled, elastic, cylindrical tank with any type of boundary conditions.

77-1139

Stresses in Column-Supported Hyperboloidal Shells Subject to Seismic Loading

P.L. Gould, H. Suryoutomo, and S.K. Sen
Dept. of Civil Engrg., Washington Univ., St. Louis, MO, Intl. J. Earthquake Engr. Struc. Dynam., 5 (1), pp 3-14 (Jan - Mar 1977) 10 figs, 13 refs
Sponsored by the National Science Foundation

Key Words: Hyperbolic parabolic shells, Seismic excitation, Spectrum analysis

The computation of stresses within a finite element displacement method analysis of a shell of revolution is considered. The common procedure of applying the kinematic and constitutive laws to the displacement functions is examined and justified for models where the displacements are represented by high-order polynomial expansions. Also, two alternative computational formats within this technique are explored.

77-1140

Parametric Instability and Limit Cycle Response of Nonlinear Elastic Shells

L. Memula
Ph.D. Thesis, Univ. of California, Berkeley, 83 pp, 1976
UM 77-4535

Key Words: Spherical shells, Parametric response, Perturbation theory

The stability of symmetrical motion of spherical shells under radial perturbation is investigated. The symmetrical motion consists of a constant finite deformation plus a harmonic motion of small amplitude.

77-1141

The Influence of Geometric Imperfections on the Free Vibrations of Thin Cylindrical Shells

S.T. Bhat

Ph.D. Thesis, The Univ. of Connecticut, 164 pp, 1976

UM 77-4250

Key Words: Cylindrical shells, Geometric imperfection effects, Transient response

A relatively thin - small thickness to radius ratio - ring and cylindrical shell have been investigated to numerically evaluate the effect of eccentricity on the first four nontrivial natural frequencies and corresponding mode shapes. The thin shell is assumed to be freely supported at the ends whereas the boundary conditions for thin ring allow it to be freely supported in space and is free to translate and rotate with rigid body motion. The ring model is studied using an energy formulation, while the thin shell is investigated using equations of dynamic equilibrium. A truncated series solution is applied to obtain numerical approximations of the eigenvalues and respective eigenvectors for different eccentricity ratios. Extensional and inextensional models of both Flügge and Love-Timoshenko ring models are considered. The shell element is based solely on the Flügge model. All the cases are investigated for two radius to thickness ratios.

77-1142

On the Role of Cross-Correlations in the Random Vibrations of Shells

I. Elishakoff

Dept. of Aeron. Engrg., Technion-Israel Inst. of Tech., Haifa, Israel, J. Sound Vib., 50 (2), pp 239-252 (Jan 22, 1977) 8 tables, 25 refs

Key Words: Shells, Random vibration, Cross correlation technique

Theoretical and numerical results are presented for the investigation of the role of cross-correlations in random shell vibration problems. The conditions of negligibility of the cross-terms are derived for a shell with hysteretic damping.

77-1143

Dynamic Interaction of Shells and Plates with the Ambient Medium

A.G. Gorshkov

Lockheed Missiles and Space Co., Palo Alto, CA, 22 pp (Oct 6, 1976) (Engl. transl. from Inzh. Zh., Mekh. Tverd. Tela (Moscow) No. 2, pp 165-178, (1976)

N77-12432

Key Words: Shells of revolution, Plates, Shock response, Submerged structures, Underwater structures

A certain class of problems from the domain of aerohydroelasticity is examined. Included in the survey are papers published in the periodical press within the last years. Fundamental attention is paid to problems related to the effect of shocks on elastic shells of revolution and to the submersion of elastic bodies in water. An analysis of research on these and similar problems is also represented in a number of monographs and in survey papers.

77-1144

Non-Linear Analysis of Vibrations of Irregular Plates

D.W. Lobitz, A.H. Nayfeh, and D.T. Mook

Sandia Laboratories, Albuquerque, NM 87115, J. Sound Vib., 50 (2), pp 203-217 (Jan 22, 1977) 4 figs, 16 refs

Sponsored by the U.S. Energy Res. and Development Administration and NASA

Key Words: Plates, Forced vibration, Perturbation theory

A numerical perturbation method is used to investigate the forced vibrations of irregular plates. Non-linear terms associated with the midplane stretching are retained in the analysis. The numerical part of the method involves the use of linear, finite element techniques to determine the free oscillation mode shapes and frequencies and to obtain the linear midplane stress resultants caused by the midplane stretching.

77-1145

Optimal Design of a Composite-Material Plate to Maximize its Fundamental Frequency

C.W. Bert

School of Aerospace, Mech. and Nuclear Engrg., The Univ. of Oklahoma, Norman, OK 73069, J. Sound Vib., 50 (2), pp 229-237 (Jan 22, 1977) 3 figs, 2 tables, 18 refs

Key Words: Plates, Laminates, Optimization, Fundamental frequency

A rationale is presented for determining the optimal laminate design for a thin plate consisting of multiple layers of equithickness composite material. The optimal design criterion is maximization of the fundamental frequency of small-amplitude, free flexural vibration. The rationale is applied to simply supported rectangular plates of carbon-fiber-reinforced plastic (CFRP) as a function of plate aspect ratio. Comparative optimal frequency data are given for plates of three practically important plate aspect ratios and laminated of four unidirectional filament-reinforced composite materials: all having epoxy matrices and fibers of boron (BFRP), carbon (CFRP), glass (GFRP) and organic fiber (OFRP).

77-1146

Forced Vibrations of Simply Supported Orthotropic Sandwich Plates

B.R. Bhat and P.K. Sinha

Structural Engineering Div., Vikram Sarabhai Space Centre, Trivandrum - 695022, India, J. Acoust. Soc. Amer., 61 (2), pp 428-435 (Feb 1977) 10 figs, 6 refs

Key Words: Plates, Sandwich laminates, Orthotropism, Forced vibrations

Force transmissibility, driving-point impedance, and transfer impedance of a simply supported rectangular orthotropic sandwich plate are investigated. The plate is driven by a sinusoidally varying point force either at the plate center or at any arbitrary location. The variation of force transmissibility and impedance with frequency, and the manner in which this is influenced by the various sandwich-plate parameters are studied and presented graphically.

77-1147

Moving-Load Stability of a Circular Plate on a Floating Central Collar

C.D. Mote, Jr.

Dept. of Mech. Engrg., Univ. of California, Berkeley, CA 94720, J. Acoust. Soc. Amer., 61 (2), pp 439-447 (Feb 1977) 8 figs, 4 tables, 9 refs

Key Words: Circular plates, Moving loads, Stability, Saws, Tools

The eigenvalue problem and transverse response of a circular plate, that is free at the periphery and that slides freely along the axis of symmetry without bending rotation, are theoretically analyzed. The occurance of eigenvalues in the boundary conditions is accounted for with an extended operator definition in the equation of transverse motion. The stability of these plates under concentrated loads moving at uniform speed is analyzed for harmonic transverse loading and loading proportional to transverse displacement and velocity. The harmonic loading case leads to a classical, critical-speed analysis. The proportional loading case represents the excitation of the plate by transverse position guides. The number, orientation, and mechanical properties of the guides determine the transverse stability of the plate-guide dynamic system.

77-1148

Forced Vibration of Tube Support Plates in Power Plant Condensers, With Friction Damping

R. Pigott

Technology Development, Steam Turbine Div., Westinghouse Electric Corp., Philadelphia, PA, J. Engr. Power, Trans. ASME, 99 (1), pp 106-114 (Jan 1977) 14 figs, 12 refs

Key Words: Plates, Electric power plants, Forced vibration, Coulomb friction

A method is given for analyzing the vibration of tube support plates in power plant condensers. The tubes are not fastened to the support plates and, therefore, their effect is simply that of a frictional restraint which is modeled as a massless elastic-plastic foundation. The technique given is an application of the Kryloff-Bogoliuboff method. The stability of the steady-state solution is also considered and it is shown that "jump" phenomenon exist for some conditions.

77-1149

Gaussian Ideal Impulsive Loading of Rigid Viscoplastic Plates

R.J. Hayduk

Langley Research Center, NASA, Langley Station, VA, In: NASA. Langley Res. Center Advan. in Eng. Sci., Vol. 2, 1976, pp 595-616 (see N77-10265) N77-10286

Key Words: Plates, Viscoelastic properties, Impact response

The response of a thin, rigid, viscoplastic plate subjected to a spatially axisymmetric Gaussian ideal impulse loading was studied analytically. The Gaussian ideal impulse distribution instantaneously imparts a Gaussian initial velocity distribution to the plate, except at the fixed boundary. The plate deforms with monotonically increasing deflections until the initial dynamic energy is completely dissipated in plastic work. The simply supported plate of uniform thickness obeys the von Mises yield criterion and a generalized constitutive equation for rigid, viscoplastic materials. For the small deflection bending response of the plate, neglecting the transverse shear stress in the yield condition and rotary inertia in the equations of dynamic equilibrium, the governing system of equations is essentially nonlinear. A proportional loading technique, known to give excellent approximations of the exact solution for the uniform load case, was used to linearize the problem and obtain analytical solution in the form of eigenvalue expansions. The linearized governing equations required the knowledge of the collapse load of the corresponding static problem.

77-1150

Stability and Vibration Analysis of Rectangular Plates of Variable Thickness by the Finite Element Method

Z. Dzygadlo and J. Kierkowski

Polish Academy of Sciences, Inst. of Fundamental Technological Research, Warszawa, Poland, J. of Technical Physics, 17 (4), pp 409-422 (1976) 6 figs, 2 tables, 4 refs

Key Words: Rectangular plates, Variable cross section, Finite element technique, Stability, Vibration response

The method of numerical analysis of static and dynamic problems of plates of variable thickness based on the method of finite elements has a number of advantages as compared with classical approximate methods. In view of the recurrence form of the relations used for the determination of the characteristic equations and the vibration modes it is fairly well suited for computer analysis. The displacement of the plate, its derivative with respect to the variable x, the bending moment and the transverse force are determined simultaneously without the necessity of differentiation, therefore, with uniform accuracy, which is an essential advantage of the method.

77-1151

Vibration Studies on Some Integral Rib-Stiffened Plates

M.D. Olson and C.R. Hazell

Dept. of Engrg., Univ. of British Columbia, Vancouver, Canada, J. Sound Vib., 50 (1), pp 43-61 (Jan 8, 1977) 11 figs, 18 refs

Sponsored by the National Research Council of Canada

Key Words: Plates, Ribs (supports), Stiffened plates, Finite element technique, Holographic techniques, Vibration response

Results from a theoretical and experimental comparison study of the vibrations of four integrally machined rib-stiffened plates are presented. Two plates had one rib-stiffener and two plates had two rib-stiffeners. The finite element method was used for the theoretical predictions and real-time laser holography was used for the experimental verifications. The first twenty-four vibration modes were predicted and measured for each plate, and detailed comparisons are presented. Reasonable good quantitative agreement was obtained in all cases for both frequencies and mode shapes.

77-1152

Higher-Order Effects of Initial Deformation on the Vibrations of Crystal Plates

X. Markenscoff

Dept. of Engrg. Science and Mech., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Acoust. Soc. Amer., 61 (2), pp 436-438 (Feb 1977) 1 table, 10 refs

Key Words: Plates, Flexural vibrations, Initial deformation effects

A system of plate equations for the thickness-shear and flexural vibrations superposed on large initial deflection due to bending is derived; in the stress-strain relations the terms associated with the fourth-order elastic stiffness coefficients are retained. An explicit formula for the change in the fundamental cutoff thickness shear frequency is obtained and the effects of the terms associated with the fourth-order constraints appear to be significant for large gradients of the rotation angles.

77-1153

A Comprehensive Free Vibration Analysis of Rectangular Plates with Two Opposite Edges Simply Supported

D.J. Gorman

Univ. of Ottawa, Ontario, Canada, ASME Paper No. 76-WA/DE-13

Key Words: Rectangular plates, Transient response

A comprehensive free vibration analysis of the family of rectangular plates with simple (hinged) support at two opposite edges has been conducted. A concise discussion of the solution to the governing differential equation and the frequency limits is presented.

77-1154

A Simplified Approach to the Large Amplitude Vibration of Plates and Membranes

J. Mazumdar and R. Jones

Dept. of Applied Mathematics, The University of Adelaide, Adelaide, South Australia, J. Sound Vib., 50 (3), pp 389-397 (Feb 8, 1977) 5 figs, 21 refs

Key Words: Plates, Membranes, Flexural vibrations

The large amplitude transverse vibration of plates is analyzed by using the method of constant deflection contour lines and the well-known Berger method. By letting the plate stiffness tend to zero, the case of the large amplitude vibration of membranes is treated in a simple and uniform manner. Several illustrative examples are discussed, all details of which are explained by graphs.

77-1155

Large Amplitude Vibrations of Circular Plates with Varying Thickness

K.K. Raju
Structural Engrg. Div., Vikram Sarabhai Space Centre, Trivandrum - 695022, India, J. Sound Vib., 50 (3), pp 399-403 (Feb 8, 1977) 2 figs, 6 tables, 3 refs

Key Words: Circular plates, Variable cross section, Finite element technique

A simple finite element formulation is presented to evaluate the large amplitude vibration frequencies of orthotropic circular plates with linearly varying thicknesses. Period ratios are presented in tables and figures for different values of the orthotropy and taper parameters.

RINGS

77-1156

In-Plane Vibration of a Thick Circular Ring

J. Kirkhope
Dept. of Engrg., Carlton Univ., Ottawa, Ontario, Canada, J. Sound Vib., 50 (2), pp 219-227 (Jan 22, 1977) 3 figs, 6 tables, 14 refs

Sponsored by the National Research Council of Canada

Key Words: Rings, Transverse shear deformation effects, Rotatory inertia effects

Dynamic stiffness matrices are derived for the in-plane vibration of thick circular rings where the effects of transverse shear and rotatory inertia cannot be neglected. The accuracy of the expressions is demonstrated by comparison of calculated and experimental frequencies for very thick rings of circular and rectangular cross-section.

STRUCTURAL

(Also see Nos. 1103, 1179)

77-1157

Dynamic Properties of Asymmetric Wall-Frame Structures

A. Rutenberg, W.K. Tso, and A.C. Heidebrecht
Dept. of Civil Engrg., Technion-Israel Inst. of Tech., Haifa, Israel, Intl. J. Earthquake Engr. Struc. Dynam., 5 (1), pp 41-51 (Jan - Mar 1977) 2 figs, 4 tables, 8 refs

Key Words: Walls, Framed structures, Natural frequencies, Mode shapes

An approximate method is proposed for evaluation of the natural frequencies and mode shapes of uniform asymmetric wall-frame structures. An exact solution is first given for the case in which the coefficient matrix of the dynamic equilibrium equations satisfies certain conditions. Using perturbation analysis, the method is then applied to the more general case in which these conditions are only approximately satisfied. A numerical example is presented to illustrate the technique.

77-1158

Flow-Induced Vibrations Resulting from Karman Vortex Trails

Y.N. Chen
British Library Lending Div., Boston Spa, UK, Rept. No. BLL-Risley-TR-2994-9091.9F, 16 pp (Mar 25, 1976) (Engl. transl. from Energietechnik (Leipzig), 25 (5), pp 200-205 (May 1975))
N77-11988
Availability: British Library Lending Div., Boston Spa, England

Key Words: Structural elements, Electric power plants, Cylinders, Tubes, Plates, Fluid-induced excitation

Karman eddy streets, formed on flow around structural elements of a power station and individual cylinders, tube bundles, plates, which induce periodic dynamic forces transverse to the flow at these elements are described. The Karman eddy street beyond a plate exposed to longitudinal flow depends largely on the outlet edge shape of the plate.

77-1159

Primer on Transient Analysis of Complex Structures at Resonance

A. Levy

Grumman Aerospace Corp., Bethpage, NY, ASME Paper No. 76-WA/DE-10

Key Words: Structural response, Periodic response, Transient response, Steady-state response, Component mode synthesis

A simplified analysis of the transient and steady-state response of a complex structural system with low damping due to an oscillating resonant forced vibration is presented. Using a modal synthesis approach, the phenomenon of a complex structure responding in a transient manner to a resonant frequency forcing function is described, viz., the structure deforms in space to its corresponding natural mode shape and grows in time asymptotically to its steady-state motion, as if it were a single-degree-of-freedom system. A comparison of the single mode solution with the complete solution is shown to yield an excellent approximation.

77-1160

Static and Dynamic Calculation of Machine Tool Frames

B. Lull

VEB Werkzeugmaschinenkombinat, Fritz Heckert, Karl-Marx,Stadt, Ger. Dem. Rep., Maschinenbautechnik, 26 (1), pp 10-13 (Jan 1977) 5 figs, 8 refs

(In German)

Key Words: Machine tools, Dynamic response, Beams, Finite element technique, Computer programs

Static and dynamic analysis of machine tool frames is presented based on the beam theory and finite element technique. Several computer programs are reviewed.

77-1161

Computer Program RASTADYN for the Calculation of Machine Frames and Machine Elements

H. Aurich and L. Franz

Technische Hochschule Karl-Marx Stadt, German Democratic Republic, Maschinenbautechnik, 26 (1), pp 8-9 (Jan 1977) 3 figs, 7 refs

(In German)

Key Words: Machinery, Frames, Machinery components, Computer programs, Finite element technique

A computer program RASTADYN is described for the static and dynamic analysis of machine frames and machine elements by means of finite element technique.

SYSTEMS

ABSORBER

(Also see Nos. 1057, 1068)

77-1162

Impact Absorber with Two-Stage, Variable Area Orifice Hydraulic Damper

M.S. Hundal

Dept. of Mech. Engrg., Univ. of Vermont, Burlington, VT 05401, J. Sound Vib., 50 (2), pp 195-202 (Jan 22, 1977) 4 figs, 6 tables, 7 refs

Key Words: Shock absorbers, Hydraulic dampers

Analysis of an impact absorber consisting of a linear spring in parallel with an hydraulic damper with variable area orifice is presented. The orifice area varies in two stages in order to overcome the deteriorating effect of fluid compressibility on the maxiumum acceleration of the impacting mass. During the first stage the orifice is closed, causing a rapid build-up of pressure; during the second stage the orifice area varies in such a way as to provide constant acceleration during the remainder of the stroke.

77-1163

Design of Impact Absorber with Quadratic Damping

M.S. Hundal

Univ. of Vermont, Burlington, VT, ASME Paper No. 76-WA/DE-12

Key Words: Shock absorbers, Quadratic damping

An impact absorber with linear elastic element in parallel with quadratic-law damper is analyzed. A dimensionless parameter, the quadratic damping ratio, is identified. Closed-form solutions are presented in terms of this one parameter. Conditions for optimum performance are derived. Response of absorbers with linear and quadratic-law friction of optimum design is compared.

77-1164

Optimum Preview Control of Vehicle Air Suspensions

Y. Iwata and M. Nakano

Dept. of Engrg., Tokyo Metropolitan Univ., Setagaya-ku, Tokyo, Japan, Bull. JSME, 19 (138), pp 1485-1489 (Dec 1976) 11 figs, 5 refs

Key Words: Active absorption, Vibration absorption (equipment), Suspension systems (vehicles)

In this paper, the active vibration abosrber controlling the pressure of the air spring is applied to a preview control system of a vehicle suspension. The front half-part of the vehicle functions as the sensor for the vibration absorption of the rear half-part. The design criterion for the optimum preview control absorber is the minimization of the rms value of the acceleration under the specified constraints on the relative displacement. The optimum preview system is realized by the feedforward and feedback compensation systems. Chang's optimum control theory is applied to the optimization.

77-1165

Optimal Cantilever Dynamic Vibration Absorbers

R.G. Jacquot and J.E. Foster

Dept. of Electrical Engrg., Univ. of Wyoming, Laramie, WY, J. Engr. Indus., Trans. ASME, 99 (1), pp 138-141 (Feb 1977) 8 figs, 18 refs

Key Words: Dynamic vibration absorption (equipment), Cantilever beams

This work considers the use of a double-ended cantilever beam as a distributed parameter dynamic vibration absorber applied to a single-degree-of-freedom system in the presence of sinusoidal forces. The problem is analyzed exactly and by an energy approach using a single mode approximation for the cantilever beam. The results for both techniques compare favorably and damping is introduced in the form of a complex beam modulus. Optimal tuning and optimal damping parameters are found for a given ratio of absorber mass to main mass.

NOISE REDUCTION

(See Nos. 1122, 1123, 1170, 1216, 1217, 1233)

ACTIVE ISOLATION

77-1166

Dynamics of Linear Systems with Semiactive Force Generators

R.R. Allen

Univ. of California, Los Angeles, CA 90024, AIAA J., 15 (2), pp 137-144 (Feb 1977) 8 figs, 18 refs

Key Words: Semiactive isolation

A semiactive element produces control forces in a dynamic system by controlled variation of a resistive parameter. Control constraints exist making the output of a semiactive element complex and nonlinear even for linear feedback control laws. State equations are derived for a general linear system with an arbitrary number of semiactive elements. Numerical results demonstrate performance superior to passive suspensions and comparable to fully-active control.

AIRCRAFT

77-1167

The Generation and Radiation of Supersonic Jet Noise. Volume IV. Shock-Associated Noise Data

H.K. Tanna, P.D. Dean, and R.H. Burrin

Lockheed-Georgia Co., Marietta, GA, Rept. No. AFAPL-TR-76-65-Vol-4, 416 pp (June 23, 1976) (see also Vol. 2, AD-A032 881)
AD-A032 883/1GA

Key Words: Aircraft noise, Noise generation, Shock excitation

The characteristics of the sound field of shock-containing under-expanded jets are studied by measuring the noise from a two-inch diameter convergent nozzle over an extensive envelope of supercritical jet operating conditions. The results are presented in this Volume in a systematic manner in the form of narrowband spectra.

77-1168

The Generation and Radiation of Supersonic Jet Noise. Volume II. Studies of Jet Noise, Turbulence Structure and Laser Velocimetry

H.E. Plumblee, Jr., R.H. Burrin, J.C. Lau, C. L. Morfey, and P.J. Morris

Lockheed-Georgia Co., Marietta, GA., Rept. No. AFAPL-TR-76-65-Vol-2, 472 pp (June 23, 1976) (see also Vol. 3, AD-A032 882)
AD-A032 881/5GA

Key Words: Aircraft noise, Jet noise

This volume discusses turbulent mixing noise tests and observations relative to effects of temperature and Mach number on intensity, directivity, and spectra; numerical solutions of the Lilley theory for sound radiated from point sources simulating small-scale turbulence noise sources, and comparisons of these solutions with experimental data relating to temperature and velocity effects on directivity and spectra; the theory describing the development of the large-scale coherent motion of the jet structure and the far-field noise radiated from this turbulence; a detailed discussion and interpretation of the jet turbulence and mean velocity data; and a comprehensive description of the shock-associated noise tests, a preliminary description of the broadband shock-associated noise model, and a discussion of shock-associated noise in the overall jet noise picture.

77-1169

Calculation of Vibration Modes and Resonance Frequencies of the Northrop NF-5

H.H. Ottens

Structures and Materials Div., National Aerospace Lab., Amsterdam, Netherlands, Rept. No. NLR-TR-75050-U; NLR-TR-74012-U, 71 pp (Apr 15, 1975)

N77-11450

Key Words: Aircraft, Wing stores, Resonant frequency, Normal modes, Component mode analysis, Finite element technique

A calculation of global values of resonance frequencies, vibration modes, and generalized masses was made for the Northrop NF-5 in order to investigate the potentialities of both the finite element method and the component mode method in obtaining these characteristics. The configurations considered involve full tiptanks, 70 lbs stores at the outboard pylons, full or empty 275 USG tanks at the inboard pylons, and a 150 USG tank at the center line pylon. For these configurations, a comparison was made with ground vibration test results.

77-1170

Practical Noise Abatement for a General Aviation Airport

W.S. Hamilton

Louisville and Jefferson County Air Board, Louisville, KY, S/V, Sound Vib., 11 (2), pp 24-27 (Feb 1977) 2 figs, 2 tables

Key Words: Aircraft noise, Airports, Noise reduction

Bowman Field, like a number of other major general aviation airports, has a large number of operations by propeller-driven small airplanes. In response to increasing noise complaints from neighbors, a comprehensive noise abatement program has been developed which should find applicability at similar facilities. The following article discusses the program and emphasizes the results of noise level monitoring and a tradeoff analysis of possible abatement techniques.

77-1171

Mechanical Systems Model for Dynamic Soil-Wheel Interaction

C. Wang

Ph.D. Thesis, State Univ. of New York at Buffalo, 246 pp, 1976

UM 77-3594

Key Words: Interaction: wheel-pavement, Aircraft landing areas

Operation of aircraft from unpaved airfields involves the complex problems of gear-soil interaction. To design aircraft for these operations, it is necessary to estimate how much wheel sinkage (rut depth) and drag force are to be encountered. This study has its primary objective to establish the relationships for drag force and sinkage for a rolling, vertically-oscillating single wheel on soil as function of soil properties, tire characteristics, vertical load and forward speed.

77-1172

A Method of Analysis for General Aviation Airplane Structural Crashworthiness

G. Wittlin and M.A. Gamon

Lockheed-California Co., Burbank, CA., Rept. No. FAA-RD-76-123, 317 pp (Sept 1976)

AD-A032 415/2GA

Key Words: Crash research (aircraft), Computer programs

The results of an effort to develop a method of analysis of the structural response of general aviation airplane subjected to a crash environment are presented. A review and evaluation of 8491 obtained from National Transportation Safety Board tapes are presented. Eighteen (18) accident cases from the FAA Civil Aeromedical Institute files are discussed. The performance parameters and structural design characteristics associated with 61 general aviation airplane models are used to establish several airplane categories for light fixed-wing aircraft. An accident data computer program, developed by the Cessna Aircraft Company, is presented. The requirements for performing computerized crash analysis of general aviation airplanes during probable accident conditions are described.

77-1173
A Method for the Analysis of Nonlinearities in Aircraft Dynamic Response to Atmospheric Turbulence
K. Sidwell
Langley Research Center, NASA, Langley Station, VA, Rept. No. NASA-TN-D-8265, L-10487, 83 pp (Nov 1976)
N77-11992

Key Words: Aircraft, Dynamic response, Turbulence

An analytical method is developed which combines the equivalent linearization technique for the analysis of the response of nonlinear dynamic systems with the amplitude modulated random process (Press model) for atmospheric turbulence. The method is initially applied to a bilinear spring system. The analysis of the response shows good agreement with exact results obtained by the Fokker-Planck equation. The method is then applied to an example of control-surface displacement limiting in an aircraft with a pitch-hold autopilot.

77-1174
Comparisons of Several Aerodynamic Methods for Application to Dynamic Loads Analyses. Final Report
R.K. Kroll and R.D. Miller
Boeing Commercial Airplane Co., Seattle, WA, Rept. No. NASA-CR-137720; D6-44111, 127 pp (July 1976)
N77-13001

Key Words: Aircraft, Wind-induced excitation

The results of a study are presented in which the applicability at subsonic speeds of several aerodynamic methods for predicting dynamic gust loads on aircraft, including active control systems, was examined and compared. These aerodynamic methods varied from steady state to an advanced unsteady aerodynamic formulation. Brief descriptions of the structural and aerodynamic representations and of the motion and load equations are presented. Comparisons of numerical results achieved using the various aerodynamic methods are shown in detail.

77-1175
Inflight Flutter Clearance Testing of Aircraft
J. Hermayer
Test Instrumentation, Fairchild Republic Co., Farmingdale, L.I., NY, Closed Loop, 7 (1), pp 10-17 (Feb 1977) 10 figs

Key Words: Aircraft vibration, Flutter, Vibration tests

Fairchild Republic Company implemented an MTS electro-hydraulically driven shaker system to perform an inflight program of flutter clearance for the Fairchild A-10 Close Air Support aircraft. Based on the experience of other aircraft companies and Fairchild's analysis of the characteristics and requirements of the A-10 aircraft, it was decided that the electro-hydraulically driven system would provide all the operational features which were desired in an inflight shaker system.

BRIDGES

77-1176
Method for Determination of Aerodynamic Characteristics of a Suspension Bridge Using a Sectional Model
W. Chea
Dept. of Aeron. Engrg., Bristol Univ., UK, Rept. No. BU-202, 50 pp (June 1976)
N77-13468

Key Words: Suspension bridges, Wind-induced excitation, Aerodynamic response, Testing techniques

An experimental technique to predict oscillations and prevent damage of suspension bridges in high winds is described. Oscillatory derivatives can be deduced from data collected in the constant-amplitude sinusoidal forcing of a simple sectional model of a bridge deck structure. Both vertical translation and torsional freedoms were allowed. The apparatus for such tests was built and shown to operate as desired, but the tests were not sufficiently complete to prove that the method is entirely adequate.

BUILDING

(Also see No. 1102)

77-1177
Behavior of Inelastic Multi-Story Structures Subjected to 2-D Earthquakes
K.B. Oster
Ph.D. Thesis, Univ. of Missouri-Rolla, 269 pp, 1976
UM 77-5562

Key Words: Multistory buildings, Earthquake response, Mathematical models, Lumped parameter method

An analytical study is presented for the behavior of multistory framed structures subjected to the interaction of horizontal and vertical components of an earthquake. Typical structures having three to ten stories and one to three bays are studied on the basis of a lumped mass model with elastic, elasto-plastic and bilinear material behavior. The studies include the characteristics of energy absorption in the form of input energy, kinetic energy, elastic strain energy, and dissipated strain and damping energy; the reduction of plastic moment capacity of columns; ductility and excursion ratios; and the P-delta effect as well as the effect of two different lumped mass models on the response parameters.

77-1178

Coupled Lateral Torsional Response of Buildings to Ground Shaking

C.L. Kan

Ph.D. Thesis, Univ. of California, Berkeley, 174 pp, 1976

UM 77-4491

Key Words: Buildings, Earthquake response, Coupled response, Lateral response, Torsional response

This study of earthquake response of buildings for which the lateral motions are coupled with the torsional motion is presented in three parts. The elastic response of torsionally coupled one-story buildings to earthquake ground motion, characterized by idealized shapes for the response spectrum, is studied. A simple procedure is developed for the analysis of the elastic response of a particular class of torsionally coupled multistory buildings to earthquake ground motion, characterized by smooth response spectra. With the aid of perturbation analysis of vibration frequencies and mode shapes it is shown that any lower vibration mode of a torsionally coupled building may be approximated as a linear combination of three vibration modes of the corresponding torsionally uncoupled system.

77-1179

Earthquake Response of Steel-Framed Multistorey Buildings with Set-Backs

J.L. Humar and E.W. Wright

Dept. of Civil Engrg., Carleton Univ., Ottawa, Canada, Intl. J. Earthquake Engr. Struc. Dynam., 5 (1), pp 15-39 (Jan - Mar 1977) 13 figs, 2 tables, 12 refs

Key Words: Multistory buildings, Earthquake response, Seismic excitation

A study is made of the dynamic behavior of multistory steel rigid-frame buildings with set-back towers. The effects of set-backs upon the building frequencies and mode shapes are examined. Then the effects of set-backs on seismic response are investigated by analyzing the response of a series of set-back building frame models to the El Centro ground motion. Finally, the computed responses to the El Centro earthquake are compared with some code provisions dealing with the seismic design of set-back buldings.

77-1180

Methodology for Hazard Risk Evaluation of Buildings. Volume III. Demonstration Manual

J.H. Wiggins, J.D. Chrostowski, and T.K. Hasselman

Wiggins (J.H.) Co., Redondo Beach, CA, Rept. No. NBS-CGR-75-38, 73 pp (Dec 14, 1973)

PB-261 021/0GA

Key Words: Buildings, Earthquake damage, Computer programs

A methodology is presented for evaluation of existing buildings to determine the risk to life safety from natural disasters and to estimate the amount of expected damage. Damage to both structural and non-structural building components resulting from the extreme environments produced by earthquakes, hurricanes, and tornados is considered.

77-1181

Nonlinear Response Spectra for Probabilistic Seismic Design and Damage Assessment of Reinforced Concrete Structures

M. Murakami and J. Penzien

Earthquake Engrg. Research Center, California Univ., Berkeley, CA, Rept. No. EERC-75-38, 99 pp (Nov 1975)

PB-259 530/4GA

Key Words: Reinforced concrete, Buildings, Seismic design, Computer programs, Earthquake resistant structures

In the investigation reported herein, twenty each of five different types of artificial earthquake accelerograms were generated for computing nonlinear response spectra of five structural models representing reinforced concrete buildings. To serve as a basis for probabilistic design and damage assessment, mean values and standard deviations of ductility factors were determined for each model having a range of prescribed strength values and having a range of natural periods.

77-1182

Dynamic Reactions of Frame Buildings During Blowout of Surface Panels by Shock Loading. Loading of Frame Buildings by Shock Waves

W. Koerner
Ernst-Mach-Inst., Freiburg, West Germany, Rept. No. 2/76, 49 pp (June 1976)
(In German)
N77-13469

Key Words: Buildings, Nuclear explosion effects, Computer programs

Two computer programs are presented for closed rectangular buildings and open frame buildings to determine the loading of these buildings caused by the shock wave of a nuclear explosion. The input values are the distance to the explosion center, the explosion yield, and the dimensions of the building. The programs produce mean vlaues of the pressure as function of time at characteristic surfaces of the building. The punched cards are input cards for the NONSAP program, a computing program for static and dynamic response of nonlinear systems.

77-1183
Active Control of Building Structures Subjected to Wind Loads
S. Sae-Ung
Ph.D. Thesis, Purdue Univ., 93 pp, 1976
UM 77-1771

Key Words: Buildings, Wind-induced excitation

The purpose of this study is to find feasible feedback comfort and/or safety control functions for building structures subjected to wind force excitations. The criteria for human comfort and safety were chosen on the basis of a literature review. A vibrational model of multistory building structures subjected to wind force excitation, comfort and/or safety control was formulated and solutions were obtained with the use of the Monte Carlo method. The mechanical principles for the safety and comfort control laws were derived. Through a sequence of conjectures on the basis of these mechanical principles, an effective law was found for comfort control. Meanwhile, the combination of the safety and comfort control functions by assigning first priority to safety was found to be ineffective.

77-1184
A Study of the Coupled Lateral and Torsional Response of Tall Buildings to Wind Loadings
C.P. Patrickson
Ph.D. Thesis, Univ. of California, Los Angeles, 211 pp, 1976
UM 77-2924

Key Words: Buildings, Wind-induced excitation, Coupled response, Lateral response, Torsional response

The dynamic response of tall buildings to wind loads including the torsional degree of freedom is investigated using deterministic and probabilistic analytical methods. The fundamental meteorological, aerodynamic and structural models used in the problem are described, and consistent with those models, expressions for the response are derived.

CONSTRUCTION
(See No. 1195)

FOUNDATIONS AND EARTH
(Also see Nos. 1171, 1234)

77-1185
Earthquake Analysis of Arch Dam-Foundation Systems
S. Mojtahedi
Ph.D. Thesis, Univ. of California, Berkeley, 136 pp, 1976
UM 77-4545

Key Words: Dams, Interaction: structure-foundation, Earthquake response

With particular emphasis given to arch dams, selected topics related to the earthquake analysis of structure-foundation systems by the finite element procedure are examined. After a brief review of the seismological background it is noted that gross simplifying assumptions are made in practice in the definition of the earthquake input to structure-foundation systems. One important purpose of the present work is to reduce these limitations. A brief description of a previously developed finite element program for the analysis of arch dams is presented. The mesh generation algorithms of the program are utilized in the subsequent studies.

77-1886
Sluice Pressures, Gate Vibrations, and Stilling Basin Wall Pressures, Libby Dam, Kootenai River, Montana
E.D. Hart and A.R. Tool
Army Engineer Waterways Experiment Station, Vicksburg, MS., Rept. No. WES-TR-H-76-17, 62 pp (Oct 1976)
AD-A032 665/2GA

Key Words: Dams, Cavitation, Dynamic response

Two of the three Libby Dam sluices suffered cavitation damage after a short period of operation. During this period of operation, extreme noise was heard and structural movement suspected. Prototype studies were conducted to monitor the sluice pressure fluctuation amplitudes and frequencies as well as sluice gate and structural vibrations. In addition, stilling basin wall pressures were measured during spillway releases.

77-1187

Biaxial Slip of a Mass on a Foundation Subjected to Earthquake Motions

S.H. Crandall and S.S. Lee

Dept. of Mech. Engrg., Massachusetts Inst. of Tech., Cambridge, MA 02139, Ing. Arch., 45 (5/6), pp 361-370 (1976)

Key Words: Foundations, Seismic excitation, Vibration isolation, Seismic design

The relative motion of a rigid mass on a horizontal foundation undergoing biaxial random motion in the horizontal plane is studied under the assumption that Coulomb friction acts between the mass and the foundation. The displacement of the mass with respect to the foundation is a two-dimensional random walk whose statistical parameters depend nonlinearly on the intensity and correlation of the biaxial excitation. Analytical results are obtained via the Fokker-Planck equation and the Equivalent Linearization procedure and simulation results are obtained via the digital computer. These results may be useful for predicting the accumulated slip of a stiff compact structure free to slide on its foundation during an earthquake.

HELICOPTERS

77-1188

Vibration of Helicopters

G.T.S. Done

Dept. of Mechanical Engrg., Univ. of Edinburgh, UK, Shock Vib. Dig., 9 (1), pp 5-13 (Jan 1977) 5 figs, 21 refs

Key Words: Helicopters, Forced vibration, Vibration control, Vibration isolation, Vibration absorption, Structural design, Reviews

This review describes helicopter airframe forced vibration excitation and response. Methods and hardware for vibration control including structural modification, isolation, absorbers, and rotor control are described.

77-1189

Full-Scale Crash Test of a CH-47C Helicopter

C.B. Castle

Langley Research Center, NASA, Langley Station, VA, Rept. No. NASA-TM-X-3412; L-10854, 38 pp (Dec 1976)

N77-12027

Key Words: Helicopters, Helicopter seats, Crash research (aircraft)

A full-scale crash test of a large troop/cargo carrying CH-47C helicopter was conducted at the Langley impact dynamics research facility. The crash test of this large helicopter was performed as part of a joint U.S. Army-NASA helicopter test program to provide dynamic structural and seat response data. The test, the procedures employed, the instrumentation, a general assessment of the resulting damage, and typical levels of accelerations experienced during the crash are reported. Various energy-absorbing seating systems for crew and troops were installed and instrumented to provide data for use in the development of design criteria for future aircraft.

HUMAN

77-1190

An Experimental Study for Determining Human Discomfort Response to Roll Vibration

J.D. Leatherwood, T.K. Dempsey, and S.A. Clevenson

Langley Research Center, NASA, Langley Station, VA, Rept. No. NASA-TN-D-8266; L-10789, 29 pp (Nov 1976)

N77-11666

Key Words: Ride dynamics, Human response, Measurement techniques, Measuring instruments

An experimental study using a passenger ride quality apparatus (PRQA) was conducted to determine the subjective reactions of passengers to roll vibrations. The data obtained illustrate the effect upon human comfort of several roll-vibration parameters; namely, roll acceleration level, roll frequency, and seat location (i.e., distance from axis of rotation). Results of an analysis of variance indicated that seat location had no effect on discomfort ratings of roll vibrations. The effect of roll acceleration level was significant, and discomfort ratings increased markedly with increasing roll acceleration level at all roll frequencies investigated.

ISOLATION

(Also see No. 1057)

77-1191

On Some Problems Associated with Vibration Isolation of Ship Machinery

J.A. Golinski

Dept. of Engrg of Environmental Protection, Technical Univ. of Wroclaw, Wroclaw, Poland, J. Engr. Indus., Trans. ASME, 99 (1), pp 24-30 (Feb 1977) 8 figs, 9 refs

Key Words: Shipboard machinery, Vibration isolators

Vibration isolators of machines installed on ships are subject to both dynamic forces involved with the working of these machines and inertia forces resulting from the rolling of the ship. In order to illustrate this better, a solution of the vibration equation of a single mass system has been analyzed, the system being excited simultaneously by a dynamic force and a motion of foundation.

77-1192

Design of Vibration Isolators Optimizing Riding Comfort

N. Fujiwara and Y. Murotsu

College of Engrg., Univ. of Osaka Prefecture, Sakai, Osaka, Japan, Bull. JSME, 19 (138), pp 1478-1484 (Dec 1976) 15 figs, 6 refs

Key Words: Vibration isolators, Ground vehicles, Passenger vehicles

This paper is concerned with the synthesis of vibration isolators optimizing the riding comfort of vehicles under random excitations. Optimum control theory in frequency domain is applied to solve the optimizing problems. The theoretical implementation has been accomplished for single- and two-degree-of-freedom systems. As design examples, the optimum vibration isolators for the systems with white noise foundation excitations and with roadway excitations are synthesized. The optimum vibration isolators thus obtained can only be mechanized with active elements rather than conventional spring-dashpot elements. It is, however, possible to set up the configuration approximately with passive elements.

77-1193

Validation of Generalized Cushioning Models for Selected Temperature Sensitive Cushioning Materials. Volume I.

R.M. Wyskida and J.D. Johannes

School of Graduate Studies and Res., Alabama Univ. in Huntsville, AL, Rept. No. RL-CR-76-7-Vol-1, 128 pp (Oct 1976) (See also Vol. 2, AD-A032 557) AD-A032 556/3GA

Key Words: Vibration isolators, Packaging materials, Shipping containers

This research report utilizes the results of previous MICOM container cushioning research efforts in the development of a validation procedure for the various cushioning material models being developed. The cushioning materials considered are: Minicel - 2 lbs/cu ft, Ethafoam - 2 lbs/cu ft, Ethafoam - 4 lbs/cu ft, Polyester Urethane - 4 lbs/cu ft, and Polyether Urethane - 3 lbs/cu ft.

77-1194

Container Cushioning Design Engineer Users Manual. (HP-9810A Version) Volume II

R.M. Wyskida, J.D. Johannes, and M.R. Wilhelm

School of Graduate Studies and Res., Alabama Univ. in Huntsville, AL, Rept. No. RL-CR-76-7-Vol-2, 145 pp (Oct 1976) (See also Vol. 1, AD-A032 556) AD-A032 557/1GA

Key Words: Shock isolators, Packaging materials, Shipping containers

This report is a container cushioning design manual.

MATERIAL HANDLING

77-1195

Noise Associated with the Winning and Processing of Sand and Aggregate

D.S.J. Higgins

W.A. Hines & Partners, Noise Control, Vib. and Insul., 8 (1), pp 13-17 (Jan 1977) 5 figs

Key Words: Construction equipment, Earth handling equipment, Noise generation

Any land-based sand and gravel working must, by the nature of the materials and the methods by which it is excavated and processed, create noise. This article outlines the various aspects of the associated noise problems which can in certain cases cause disturbance to local residents whose properties are situated within the vicinity of any such operations.

MECHANICAL

(Also see Nos. 1083, 1086, 1092, 1093, 1094, 1147)

77-1196

Mean-Square Response of a Nonlinear System to Nonstationary Random Excitation

H. Kanematsu and W.A. Nash

Dept. of Civil Engrg., Massachusetts Univ., Amherst, MA, Rept. No. AFOSR-TR-76-1243, 60 pp (Aug 1976)

AD-A033 288/2GA

Key Words: Single-degree-of-freedom systems, Mechanical systems, Random vibration, Equivalent linearization method

The transient mean-square response of a nonlinear single degree of freedom mechanical system to nonstationary random excitation characterized by the product of an envelope function and stationary Gaussian random process is determined by the equivalent linearization technique. A unit step envelope function is considered in conjunction with both correlated and white noise with zero mean.

77-1197

Mechanical Design Optimization for Transient Dynamic Response

M.H. Hsiao, E.J. Haug, Jr., and J.S. Arora

Univ. of Iowa, Iowa City, IA, ASME Paper No. 76-WA/DE-27

Key Words: Mechanical systems, Optimum design, Dynamic response

A class of optimal design problems involving transient dynamic response of mechanical systems is formulated in a state space setting. Extreme, or maximum valued cost functions and performance constraints are employed in formulation of the design problem. Three approaches for reducing the problem to a form that can be solved numerically are presented and evaluated through solution of a simple vehicle dynamic response optimal design problem.

77-1198

Improving the Acoustic Environment for In Situ Noise Measurements

O.L. Angevine

O.L. Angevine and Associates, East Aurora, NY 14052, J. Acoust. Soc. Amer., 61 (2), pp 484-486 (Feb 1977) 5 figs, 14 refs

Key Words: Machinery noise, Noise measurement, Measurement techniques

When using in situ measurements to characterize the noise of a machine in other installations, the measurement space must meet certain qualifications, as outlined by Hübner. In cases where nearby walls and other reflective surfaces interfere, such surfaces may be given a temporary sound-absorptive treatment. If the machine is symmetrical, measurements on an unobstructed side can be accepted as typcial of both sides. Temporary barriers may be used to shield measuring microphones from the direct noise of other nearby noise sources which cannot be turned off.

77-1199

Investigation of the Surface Acoustical Intensity Method for Determining the Noise Sound Power of a Large Machine In Situ

T.H. Hodgson

Center for Acoustical Studies, North Carolina State Univ., Raleigh, NC 27607, J. Acoust. Soc. Amer., 61 (2), pp 487-493 (Feb 1977) 9 figs, 2 tables, 15 refs

Key Words: Machinery noise, Noise measurement, Measurement techniques

Measurements of the surface acoustical intensity have been made on a large centrifugal chiller in order to determine the major noise-radiating areas of the machine. In addition, an examination of the coherency of these major noise-radiating areas has suggested that the total noise power can be obtained by addition of the noise power outputs of each component. The measurements were limited to A-weighted sound-power levels. The feasibility of the method has been checked by calculating the radiation efficiencies of the two dominant noise radiators.

METAL WORKING AND FORMING

(Also see No. 1128)

77-1200

Acoustic Emission of a Cutting Process

I. Grabec and P. Leskovar

Dept. of Mech. Engrg., Univ. of Ljubljana, Murnikova 2, Ljubljana, Yugoslavia, Ultrasonics, 15 (1), pp 17-20 (Jan 1977) 6 figs, 5 refs

Key Words: Metal working, Cutting, Sound generation, Acoustic spectra, Spectrum analysis

The cutting process of aluminum alloy, on a turner's lathe, was characterized by spectral analysis of the sound emitted by the process. The influence of the relevant cutting parameters on the spectral distribution are presented and a qualitative explanation of the corresponding effects is given. The possibility of using acoustic emission analysis to evaluate the sharpness of a cutting tool is shown to be hardly realizable.

77-1201

On the Doubly Regenerative Stability of a Grinder: The Combined Effect of Wheel and Workpiece Speed

R.A. Thompson
Corporate Res. and Development Center, General Electric Co., Schenectady, NY, J. Engr. Indus., Trans. ASME, 99 (1), pp 237-241 (Feb 1977) 2 figs, 2 tables, 2 refs

Key Words: Machine tools, Stability

The conditional stability of a plunge cylindrical grinder is worked out in explicit terms of wheel and workpiece speed.

PACKAGE

(Also see Nos. 1193, 1194)

77-1202

Performance Evaluation of the Container for the AN/ALE-38 Chaff Dispensing Pod Assembly

R.E. Dukes
Air Force Packaging Evaluation Agency, Wright-Patterson AFB, OH, Rept. No. PTPT-76-41, 11 pp (Nov 1976)
AD-A033 087/8GA

Key Words: Shipping containers, Vibration tests, Impact tests, Fiber composites, Reinforced plastics

Fiberglass reinforced plastic containers as an alternative to wood containers for the storage and shipment of Chaff Dispensing Pod Assemblies were investigated. Specific rough handling and environmental tests were accomplished including vibration, leak, and pendulum impact test at ambient conditions, and edgewise and cornerwise drop tests after prescribed environmental preconditioning. Test results are discussed.

PUMPS, TURBINES, FANS COMPRESSORS

(Also see No. 1090)

77-1203

Noise Generated by Low Pressure Axial Flow Fans. I: Modeling of the Turbulent Noise

T. Fukano, Y. Kodama, and Y. Senoo
Dept. of Engrg., Kyushu Univ., Fukuoka, Japan, J. Sound Vib., 50 (1), pp 63-74 (Jan 8, 1977) 9 figs, 16 refs

Key Words: Fans, Fan blades, Noise generation, Vortex shedding

A new analytical treatment is proposed for estimating the sound pressure level of turbulent noise radiated from low pressure axial flow fans. In the analysis, a physical model which is very simple but reasonable is introduced to explain the turbulent noise generation originating from the vortex shedding from rotor blades. The analytical results shows that the wake width, which is defined as the sum of the blade thickness and the displacement thickness of the boundary layer at the trailing edge of the blade, is one of the controlling factors of the turbulent noise; this has been verified experimentally by varying the wake width artificially. The estimated values are quite satisfactory.

77-1204

Noise Generated by Low Pressure Axial Flow Fans. II: Effects of Number of Blades, Chord Length and Camber of Blade

T. Fukano, Y. Kodama, and Y. Takamatsu
Dept. of Engrg., Kyushu Univ., Fukuoka, Japan, J. Sound Vib., 50 (1), pp 75-88 (Jan 8, 1977) 15 figs, 1 table, 3 refs

Key Words: Fans, Fan blades, Noise generation

In a previous paper a practical formula which correlates the sound pressure level of turbulent noise originating from an axial flow fan to the design parameters of the impeller was derived analytically by introducing a simple flow model. The validity of this formula is examined in respect to the effects of some of these parameters, such as number of blades and chord length, on the noise level. Experiments are also described on the effect of blade camber, to examine the applicability of the formula adopted for the evaluation of the wake width of the blade in the calculation of theoretical values, because the wake width plays a very important role in estimating the sound power.

77-1205

Dynamic Digital Blade Row Compression Component Stability Model. Model Validation and Analysis of Planar Pressure Pulse Generation and Two-Stage Fan Test Data

G.G. Reynolds and W.G. Steenken

Aircraft Engine Group, General Electric Co., Cincinnati, OH, Rept. No. AFAPL-TR-76-76, 294 pp (Aug 1976)

AD-A032 079/6GA

Key Words: Blades, Fans, Stability, Computer programs

The objectives of this study were to determine the range of validity of a Dynamic Digital Blade Row Compression Component Stability Computer Model by comparing the results of model simulations with previously obtained test data and to determine the manner in which a fan component responded to imposed unsteady aerodynamics by examining calculated parameters. Validation of the modeling technique was obtained by simulating a facility and test conditions where the response of a two-stage fan to planar waves was determined.

77-1206

Analytical and Experimental Investigation of the Stability of Intershaft Squeeze Film Dampers. Part I: Demonstration of Instability

D.H. Hibner, R.G. Kirk, and D.F. Buono

Pratt & Whitney Aircraft, East Hartford, CT., J. Engr. Power, Trans. ASME, 99 (1), pp 47-52 (Jan 1977) 10 figs, 3 refs

Key Words: Gas turbine engines, Turbine engines, Bearings, Viscous damping, Engine vibration, Vibration damping

Modern high-speed multishaft gas turbine engines incorporate viscous damped bearings to decrease overall system vibration and bearing loads. As viscous damper technology is applied to advanced engine design, more sophisticated analytical and experimental techniques are required to prove new concepts. This analysis will present the results of an investigation of the feasibility of damping engine vibration with a viscous damped intershaft bearing on a two-shaft gas turbine engine. Experimental results from a rotor dynamics simulation rig indicate an instability of the rotor system at speeds above a fundamental critical speed. An analytical model of the two-rotor system is presented and the results of both a classical stability analysis and a time transient response analysis verify the experimental data. The analytical model may be used to predict the stability of two-shaft engines which incorporate an intershaft damped bearing.

77-1207

Vibration of Deriaz Pumps at Dos Amigos Pumping Plant

F.O. Ruud

Special Studies and Testing Section, Mech. Branch, Div. of Design, U.S. Bureau of Reclamation, Denver, CO., J. Fluids Engr., Trans. ASME, 98 (4), pp 674-680 (Dec 1976) 7 figs, 7 refs

Sponsored by the Science Research Council

Key Words: Pumps

Severe vibration problems were encountered during initial operation of large Deriaz pumps. This paper describes those problems, the alternative solutions available, and the corrective action taken. Transient shaft vibrations prevented normal pump shutdown operation, when severe counter-rotational whirl occurred as the shaft speed decreased. Vibration at low blade angles preclude operation below half the rated flow. High intake water levels led to rotational shaft whirl in the normal operating range. Subsequent field testing evaluated various possible sources of vibration excitation, and verified the remedy of air injection into the headcover.

RAIL

(Also see Nos. 1060, 1106)

77-1208

Performance Characteristics of Freight-Car Trucks Determined Through Road Testing

R. Byrne and J.A. Andresen

South Pacific Transportation Co., San Francisco, CA., J. Engr. Indus., Trans. ASME, 99 (1), pp 196-205 (Feb 1977) 10 figs, 4 tables, 2 refs

Key Words: Railroad cars, Freight cars, Interaction: rail-wheel

The behavior of railroad freight-car trucks is described in relation to response modes developed within the truck structure and the freight car. A 70-ton capacity mechanical refrigerator car equipped with conventional-style, friction-snubbed three-piece trucks was tested under a variety of conditions to develop performance behavior over the speed range of 10 - 79 mph. Testing was conducted on tangent track and curved track. Response behavior is described in graphs showing frequencies and amplitudes of significant descriptors.

77-1209

Influence of Nonlinear Wheel/Rail Contact Geometry on Stability of Rail Vehicles

R. Hull and N.K. Cooperrider
Dept. of Mech. Engrg., Arizona State Univ., Tempe, AZ 85281, J. Engr. Indus., Trans. ASME, 99 (1), pp 172-185 (Feb 1977) 12 figs, 2 tables, 25 refs
Sponsored by the U.S. Dept. of Transportation

Key Words: *Railroad cars, Freight cars, Interaction: rail-wheel*

Nonlinear behavior caused by wheel flanges, worn wheel treads, and dry friction can have an important effect on rail-vehicle stability. In this paper the influence of such nonlinearities on the stability of rail freight vehicles is investigated using quasi-linearization techniques. Nonlinear equations of motion are presented that describe the lateral behavior of a 9-degree-of-freedom representation of a complete freight car with three-piece trucks. The nonlinear wheel/rail geometric constraint functions for the rolling radii, angle of wheel/rail contact, and wheelset roll angle are found by a numerical technique. The suspension description includes dry friction where appropriate. The hunting stability of the freight car is studied by employing describing-function techniques. Results are presented for a typical freight car with three different wheel profiles.

77-1210
Effects of Truck Design on Hunting Stability of Railway Vehicles
J.A. Hadden and E.H. Law
Dept. of Mech. Engrg., Clemson Univ., Clemson, SC, J. Engr. Indus., Trans. ASME, 99 (1), pp 163-171 (Feb 1977) 11 figs, 1 table, 16 refs
Sponsored by the U.S. Department of Transportation and AAR Research Center

Key Words: Railroad cars, Freight cars, Hunting motion

A general model of a dual-axle railway vehicle truck is derived. By suitable choices of primary suspension elements, this general model may be specialized to become a roller-bearing freight truck, a plain-bearing freight truck, a roller-bearing truck with primary suspension elements, a passenger truck, a generic model of a freight truck with interconnected wheelsets, or a rigid truck. The truck model is combined with a car body capable of lateral and roll displacements. The effects of the various design parameters on the critical speed for hunting are examined for each configuration.

77-1211
Influence of Axle Load, Track Gage, and Wheel Profile on Rail-Vehicle Hunting
D.N. Hannebrink, H.S.H. Lee, H. Weinstock, and J.K. Hedrick
Dept. of Mech. Engrg., Massachusetts Inst. of Tech., Cambridge, MA 02139, J. Engr. Indus., Trans. ASME, 99 (1), pp 186-195 (Feb 1977) 16 figs, 1 table, 13 refs
Sponsored by the Federal Railroad Administration

Key Words: Railroad cars, Freight cars, Hunting motion

Analyses have been conducted on the influence of axle load, track gage, and wheel contour on the hunting behavior of simplified models of wheelsets for typical freight- and passenger-car suspensions. The capability of the wheel flange to limit hunting oscillations is found to increase with wheel axle load.

77-1212
Hunting Stability of Rail Vehicles with Torsionally Flexible Wheelsets
G.R. Doyle, Jr. and R.H. Prause
Applied Dynamics and Acoustics Section, Battelle's Columbus Laboratories, Columbus, OH, J. Engr. Indus., Trans. ASME, 99 (1), pp 10-17 (Feb 1977) 14 figs, 2 tables, 15 refs

Key Words: Raidroad cars, Hunting motion, Wheelsets, *Torsional response*

The effects of torsionally flexible wheelsets on the hunting stability of rail vehicles have been investigated by solving the eigenproblems. The primary model is that of a single truck with two torsionally flexible wheelsets. Results for a complete car model consisting of the car body, two trucks and four torsionally flexible wheelsets are also presented for comparison.

77-1213
An Investigation of Factors Contributing to Wide Gage on Tangent Railroad Track
D.R. Ahlbeck, H.D. Harrison, and S.L. Noble
Applied Dynamics and Acoustics Section, Batelle Laboratories, Columbus, OH, J. Engr. Indus., Trans. ASME, 99 (1), pp 1-9 (Feb 1977) 9 figs, 1 table, 5 refs

Key Words: Railroad tracks, Fatigue life, Dynamic tests

Wide gage - a fatigue failure of the track to maintain the nominal lateral distance between rail heads - is one of several modes of track failure on which the AAR-FRA-RPI-TDA Track Train Dynamics Program has focused attention. To invesitgate the generation of wide gage on tangent track, experiments were conducted to measure track dynamic response and long-term fatigue life of track sections on the Union Pacific Railroad in Idaho. Results of these experiments have defined the important factors in this mode of track fatigue.

REACTORS

77-1214

A Computerized Method for Flow-Induced Random Vibration Analysis of Nuclear Reactor Internals

M.K. Au-Yang and W.H. Connelly

Babcock & Wilcox, Lynchburg, VA., ASME Paper No. 76-WA/PVP-12

Key Words: Nuclear reactor components, Fluid-induced excitation, Random vibration, Computer programs

The general analytical, numerical, and programming techniques of a computerized method for flow-induced random vibration analysis of nuclear reactor internal components is discussed. The importance of computer program modulization and its relationship to overlays are discussed. Some representative predicted vibration amplitudes, based on a typical pressurized water reactor design, are given.

77-1215

Building and Equipment Seismic Response for PWR Plants

C.W. Lin and G.J. Bohm

Westinghouse Electric Corp., Pittsburgh, PA, ASME Paper No. 76-WA/PVP-14

Key Words: Nuclear power plants, Seismic design, Buildings, Seismic response, Equipment response

Seismic qualification methods currently employed by the nuclear industry have been reviewed in detail in order to provide guidance for future system and equipment designs. Also presented are the results of a study of building and equipment seismic response survey of over 100 pressurized water reactor (PWR) plants.

RECIPROCATING MACHINE

77-1216

Structureborne Propagation of Noise in Diesel Engines

H.A. Fachbach and G.E. Thien

MTZ Motortech. Z., 37 (7/8), pp 269-274 (July/Aug 1976) 8 figs, 6 refs

(In German)

Key Words: Diesel engines, Noise generation, Noise reduction

The article discusses research performed in the following areas: noise transmission from combustion chamber to the external walls of a watercooled in-line engine, the effect of cast iron and cast aluminum crankcase materials, and the crank shaft pulley noise and vibration damping in piping systems.

ROAD

(Also see Nos. 1052, 1062, 1089, 1126, 1164, 1190, 1192)

77-1217

Truck Noise IV-A: Project Summary - The Reduction of Noise Levels on the International Harvester Quieted Truck

J.T. Shrader

Truck Div. Engrg., International Harvester Co., Fort Wayne, IN 46800, Rept. No. DOT/TST-76-89, 149 pp (June 1976) (See also Rept. No. 2, May 1975, PB-244 270)

PB-259 598/1GA

Key Words: Trucks, Noise source identification, Noise reduction

Truck noise is a complex interaction of many noise sources which can be isolated and studied on an individual basis. Significant reductions in diesel truck noise can be achieved with the current state-of-the-art by using a systematic approach on each major source of noise.

77-1218

The Cost and Safety Aspects of Quiet Tire Use

W.A. Leasure, Jr.

U.S. Dept. of Transportation, Washington, D.C., S/V, Sound Vib., 11 (2), pp 18-23 (Feb 1977) 9 figs, 2 tables, 15 refs

Key Words: Motor vehicle noise, Trucks, Tires, Noise reduction

Significant reductions in community noise levels near highways can be achieved by simultaneously controlling vehicle engine noise and tire noise. Although "fixes" have been demonstrated for most of the engine-related noise sources on trucks, tire noise remains an unsolved problem at highway speeds. Although at present no more than a superficial understanding of the mechanisms of tire noise generation exists, truck tire noise reductions can be accomplished utilizing current tire technology. From both a cost and safety point of view, the use of quieter tires provides at least equal, and, in general, advantageous performance when compared to current tire use practices.

77-1219

The Noise and Traction Characteristics of Bias-Ply Truck Tires. Volume 1. Noise and Dry Traction Findings

R.D. Ervin and R.E. Wild

Highway Safety Research Inst., Michigan Univ., Ann Arbor, MI 48103, Rept. No. UM-HSRI-PF-76-2-1, 154 pp (Jan 1976)

PB-259 926/4GA

Key Words: Truck tires, Noise generation, Tire characteristics

The project has established a data base of noise and traction characteristics for a sample of bias-ply heavy truck tires. The tire sample, representing both 'rib' and 'lug' type tread patterns, was tested according to the SAE J-57 tire noise procedure and in a variety of laboratory and over-the-road traction experiments. Dry-pavement traction results show that the noisier lug-type tires exhibit traction properties which are generally less desirable from the viewpoint of their influence on vehicle response to steering and braking. (Portions of this document are not fully legible).

77-1220

The Noise and Traction Characteristics of Bias-Ply Truck Tires. Volume 2. Wet Traction Findings

R.D. Ervin and C.C. MacAdam

Highway Safety Research Inst., Michigan Univ., Ann Arbor, MI 48103, Rept. No. UM-HSRI-76-2-2, 44 pp (Oct 1976) (See also Vol. 1, PB-259 926)

PB-259 927/2GA

Key Words: Truck tires, Noise generation, Tire characteristics

The project has established a data base of noise and traction characteristics for a sample of bias-ply heavy truck tires. The tire sample, representing both 'rib' and 'lug' type tread patterns, was tested according to the SAE J-57 tire noise procedure and in a variety of laboratory and over-the-road traction experiments.

77-1221

Truck Noise XI. Evaluation and Reduction of Heavy-Duty Truck Noise

V.A. Werner and W. Boyce

Truck R and D Center, PACCAR, Inc., Renton, WA, 98055, Rept. No. DOT-TSC-OST-76-21, 190 pp (Sept 1976)

PB-260 676/2GA

Key Words: Trucks, Diesel engines, Engine noise, Noise reduction, Cooling systems, Fans, Engine mufflers

This report describes the work performed to examine the noise sources on two common truck configurations manufactured by this company, and to evaluate the noise reduction effectiveness of retrofit hardware. The two trucks selected were Cab-Over-Engine (COE) models with engines most often ordered with these models. One was a Kenworth K-123 with a Cummins NTC-350 engine, the other a Peterbilt 352A with a Detroit Diesel 8V-71T engine. The major noise source on both trucks was the cooling fan which led to modifications involving fan changes and fan speed decreases which resulted in decreased overall noise levels.

77-1222

Acoustic Characteristics of a Car Cavity and Estimation of Interior Sound Field Produced by Vibrating Panel

S.K. Jha and N. Cheilas

Cranfield Inst. of Tech., Bedford, UK, ASME Paper No. 76-WA/DE-1

Key Words: Automobiles, Noise source identification

The acoustic characteristics of a car cavity are determined by using a half size model. The acoustic resonances of the model compare favorably with those of an actual car. It is shown that by treating the body structure as an assemblage of a number of point sources, and determining the sound pressure transfer functions for various points on the body structure, the sound pressure level inside the car cavity can be determined with good accuracy. Using this technique, the source areas in a car body, which are major contributors to the total noise produced, can be identified.

77-1223

Dynamic Tests of Breakaway Lighting Standards Using Small Automobiles

E.F. Nordlin, R.F. Prodoehl, J.P. Dusel and J.R. Stoker
Transportation Lab., California State Dept. of Transportation, Sacramento, CA., Rept. No. FHWA/RD-76-S0527, 51 pp (Dec 1975)
PB-259 910/8GA

Key Words: Collision research (automotive)

Results of a study to determine the effectiveness of the current breakaway slip base lighting standards with long mast arms when impacted by small cars are reported.

77-1224

Special Noise of Commercial Vehicles

F. Gaub and S. Jakel
Automobiltech. Z., 78 (12), pp 519-521 (Dec 1976) 7 figs, 1 ref
(In German)

Key Words: Motor vehicle noise, Engine noise

In urban traffic the overall exterior noise level produced by many of the commercial motor vehicles of today is influenced essentially by engine noise. Under certain conditions comparable or higher levels (above 90 dB(A)) can be generated by additional noise sources. Chattering, rattling and squeaking of platforms and side walls of bodies, leaf springs and drawbars, brake noise, screeching and hissing noise of relief pressure valves etc. are seldom produced from new vehicles, but they occur increasingly with the progression of wear rate. Tire noise which is also involved in determining the overall noise level at higher vehicle speeds has been measured for even and simulated uneven road surfaces.

77-1225

Control of Lateral Motions of the Terrafoil Transit Vehicle

J.E. Furman, Jr., B.J. Hartz, and R.N. Clark
Boeing Aerospace Co., Seattle, WA 98100, J. Spacecraft and Rockets, 14 (2), pp 118-123 (Feb 1977) 7 figs, 14 refs

Key Words: Ground effect machines, Lateral response, Active isolation

An active ride control system for the TERRAFOIL vehicle is described. The passenger compartment of this vehicle is supported above the roadway by long flexible struts, and its undercarriage is enclosed in an underground guideway. Lateral loads are imposed on the vehicle by cornering maneuvers, winds, and guideway roughness.

ROTORS

(Also see No. 1114)

77-1226

Torsional Amplitude Growth with Resonant Forcing

S. Doughty
Dept. of Mech. Engrg., Louisiana Tech. Univ., Ruston, LA 71270, J. Engr. Indus., Trans. ASME, 99 (1), pp 151-152 (Feb 1977) 2 tables, 4 refs

Key Words: Rotors, Critical speeds, Steady state response

Engine generator sets and other rotating equipment must often operate at speeds above one or more torsional natural frequencies. If steady-state stresses of dangerous magnitude are associated with a natural frequency below operating speed, the question arises as to how rapidly the system must be accelerated through the critical speed to avoid unacceptable amplitudes. Efforts to define an acceptable pass through often raise the question addressed here: For a dwell at the critical frequency, what is the nature of the growth to approach the resonant steady-state amplitude?

77-1227

Stability of the Stochastic Parametrically Excited Laval Shaft

W. Schweiger
PSP Ingenieur-Panung, Am Mühlanger 81, D-8031 Puchheim, West Germany, Mech. Res. Comm., 4 (1), pp 29-34 (1977)
(In German)

Key Words: Shafts, Stability, Oscillation

The stability of a Laval Shaft excited by random parametric speed oscillation is investigated. It is assumed that the drive speed is comprised of a constant portion and a superimposed random fluctuation. The mathematically simple, but physically pathological random function of white noise is used for the oscillation motion. As a result of this very drastic type of excitation -- it comprises all frequencies with equal intensity -- the possible stability range is conservative.

77-1228

Response of Long, Flexible Cantilever Beams Applied Root Motions

R.W. Fralich
Langley Research Center, NASA, Langley Station, VA, In: NASA. Langley Res. Center Advan. in Eng. Sci., Vol. 2. 1976, pp 491-499 (see N77-10265) N77-10276

Key Words: Cantilever beams, Rotors

Results are presented for an analysis of the response of long, flexible cantilever beams to applied root rotational accelerations. Maximum values of deformation, slope, bending moment, and shear are found as a function of magnitude and duration of acceleration input. Effects of tip mass and its eccentricity and rotatory inertia on the response are also investigated.

77-1229
Finite Element Simualtion of Rotor-Bearing Systems with Internal Damping
E.S. Zorzi and H.D. Nelson
Systems Dynamics AIResearch Manufacturing Co. of Arizona, Div. of the Garrett Corp., Phoenix, AZ, J. Engr. Power, Trans. ASME, 99 (1), pp 71-76 (Jan 1977) 9 figs, 1 table, 16 refs

Key Words: Rotor-bearing systems, Internal damping, Hysteretic damping, Finite element technique

The implementation of finite element simulations for the study of rotor dynamic systems has been the subject of recent publications. Since the finite element offers obvious modeling advantages, particularly in modeling large-scale systems, this study extends the linear finite element concept to provide a detailed evaluation of damped rotor stability. In this work the effects of both internal viscous and hysteretic damping have been incorporated into the finite element model. Both produce circulatory terms in the generalized equations of motion which encourages the destabilization of this nonconservative system. Results are presented for both hysteretic and viscous forms of damping. Both forms of internal damping destabilize the rotor system and induce nonsynchronous forward precession. The stabilizing effects of anisotropic bearing stiffness and external damping are also demonstrated.

SHIP
(Also see No. 1191)

77-1230
Some Aspects of Noise and Vibration on Board Tankers
A.B. Lewis
Dept. of Pure and Applied Physics, Univ. of Salford, Salford M5 4WT, UK, Noise Control Engr., 7 (3), pp 132-139 (Nov - Dec 1976) 7 figs, 3 tables, 28 refs

Key Words: Tanker ships, Noise measurement, Vibration measurement, Human response

In recent years the trend in the design of tankers has resulted in vastly increased sizes, with all-aft accommodation, higher engine powers, and the use of much higher speed engines and machinery. These factors, together with the crews' extended exposure to "full-power" noise and vibration levels, due to the pattern of rapid loading and unloading at termini, have caused considerable growth in the number of complaints from tanker personnel. A survey into the noise and vibration levels found on tankers and the consequent effects on ship employees is given.

SPACECRAFT

77-1231
Acoustic Excitation of Structures Analyzed by the Statistical Energy Method
J.J. Pocha
Hawker Siddeley Dynamics Ltd., Stevenage, UK, AIAA J., 15 (2), pp 175-181 (Feb 1977) 16 figs, 10 refs

Key Words: Spacecraft, Acoustic excitation, Statistical energy method

This paper presents the application of the Statistical Energy Method to the analysis of the acoustical response of spacecraft structures. The structures are assemblages of flat plates and cylinders interconnected in several ways. The analytic results were verified against a comprehensive test program in which representative structures were exposed to a reverberant sound field. In general, the correlation between test results and theoretical predictions was good, and indicates the manner in which the Statistical Energy Method can be used to obtain predictions in a relatively simple manner.

77-1232
Preliminary Vibration, Acoustic and Shock Design and Test Criteria for Components on the SRB, ET, and SSME
Marshall Space Flight Center, NASA, Huntsville, AL 35800, Rept. No. NASA-TM-X-64868, 586 pp (Nov 1976)
N77-12114

Key Words: Spacecraft components, Booster rockets, Tanks (containers), Design techniques, Vibration tests, Acoustic tests, Shock tests

Specifications for vibration, acoustic and shock design for components and subassemblies on the External Tank, Solid Rocket Booster, and Space Shuttle Main Engine are presented. Included are vibration, acoustic, shock, transportation, handling, and acceptance test requirements and procedures.

77-1233

Analytical Study of Lightweight Acoustic Shrouds for Shuttle Experiments and Payloads

J. Baratono and P. Rader

Martin Marietta Corp., Denver, CO., Rept. No. NASA-CR-150116, 118 pp (Oct 1976)

N77-12113

Key Words: *Shuttles (spacecraft), Shrouds, Noise reduction,* Acoustic tests, Acoustic linings

Results are presented of acoustic tests performed on an STS payload shroud simulator to determine the effects of a helium filled liner on the noise reduction characteristics. The basic test program included the following configurations: *bare shroud (baseline configuration);* shroud with empty liner; shroud with liner filled with air; and shroud with liner filled with helium.

STRUCTURAL

77-1234

Ground Shock Effects from Accidental Explosions

R.J. Odello and P. Price

Picatinny Arsenal, Dover, NJ, Rept. No. PA-TR-4995, 42 pp (Nov 1976)

AD-A033 208/0GA

Key Words: Ground shock, Explosion effects, Structural response, Vulnerability

This report describes a study of the effects of ground shock from accidental explosions on structures and their contents. Semi-empirical equations for estimating peak air-blast induced and direct-induced ground shock motions ar` presented. The design implications of ground shock effects are discussed.

USEFUL APPLICATION

77-1235

Vibrating Fiber Electrometer

J.J. Spokas

Energy Research and Development Administration, Washington, D.C., U.S. PATENT-3 924 184, 8 pp (Dec 2, 1975)

The patent relates to improved operation of a vibrating fiber electrometer hav`ng a flexible conductive fiber positioned between two deflecting electrodes.

AUTHOR INDEX

TECHNICAL NOTES

B P. Shastry, T.V.G.K. Murthy, and G.V. Rao
On Symmetries and Antisymmetries in Solving Vibration Problems Using High Precision Finite Elements
J. Sound Vib., 47 (3), pp 444-446 (Aug 8, 1976) 2 refs

R.J. Beckemeyer
Temperature Gradient Effects on Sound Propagation -- Thin Shear Layer Expansion Results
J. Sound Vib., 48 (3), pp 430-435 (Oct 8, 1976) 6 figs, 10 refs

P.J. Dickinson
Temperature Inversion Effects on Aircraft Noise Propagation
J. Sound Vib., 47 (3), pp 438-443 (Aug 8, 1976) 3 figs, 2 refs

N.W.M. Ko
Vertical Distribution of Traffic Noise -- A Preliminary Study
J. Sound Vib., 48 (4), pp 569-570 (Oct 22, 1976) 3 figs, 2 refs

P.E. Duncan
A Note on the Acoustic Effect of Non-Uniformly Distributed Stator Rows
J. Sound Vib., 48 (3), pp 441-444 (Oct 8, 1976) 2 figs, 3 refs

R.J. Beckemeyer and D.T. Sawdy
Note on a Length Effect on Reflective Acoustic Liner Performance
J. Sound Vib., 48 (3), pp 436-437 (Oct 8, 1976) 1 fig, 1 ref

K.W. Yeow
External Reverberation Times Observed in Built-Up Areas
J. Sound Vib., 48 (3), pp 438-439 (Oct 8, 1976) 1 fig, 1 ref

T.K. Hasselman
Modal Coupling in Lightly Damped Structures
AIAA J., 14 (11), pp 1627-1628 (Nov 1976) 1 fig, 5 refs

D.A. Hunt
A General Principle in Dynamic Response of Fluid-Structure Interaction
J. Appl. Mech., Trans. ASME, 43 (4), pp 697-698 (Dec 1976) 5 refs

M.J. Maurizi, R.E. Rossi, and J.A. Reyes
Vibration Frequencies for a Uniform Beam with One End Spring-Hinged and Subjected to a Translational Restraint at the Other End
J. Sound Vib., 48 (4), pp 565-568 (Oct 22, 1976) 1 fig, 14 refs

F.E. Eastep
Estimation of the Fundamental Frequency of Beams and Plates with Varying Thickness
AIAA J., 14 (11), pp 1647-1649 (Nov 1976) 2 figs, 4 refs

A. Avakian and D.E. Beskos
Use of Dynamic Stiffness Influence Coefficients in Vibrations of Non-Uniform Beams
J. Sound Vib., 47 (2), pp 292-295 (July 22, 1976) 3 figs, 7 refs

K.K. Raju and G.V. Rao
Non-Linear Vibrations of Beams Carrying a Concentrated Mass
J. Sound Vib., 48 (3), pp 445-449 (Oct 8, 1976) 1 fig, 7 refs

W. Hauger and K. Vetter
Influence of an Elastic Foundation on the Stability of a Tangentially Loaded Column
J. Sound Vib., 47 (2), pp 296-299 (July 22, 1976) 4 figs, 3 refs

A.G. Ozkul and Y. Chen
The Vibration of an Elliptic Ring Membrane
J. Appl. Mech., Trans. ASME, 43 (4), pp 692-694 (Dec 1976) 8 refs

A.V. Singh and S. Mirza
Free Axisymmetric Vibration of a Circular Plate Elastically Supported Along Two Concentric Circles
J. Sound Vib., 48 (3), pp 425-429 (Oct 8, 1976) 8 refs

PERIODICALS SCANNED

PUBLICATION AND ADDRESS	ABBREVIATION
ACTA MECHANICA Springer-Verlag New York Inc. 175 Fifth Ave. New York, NY 10010	Acta Mech.
ACUSTICA S. Hirzel Verlag, Postfach 347 D-700 Stuttgart 1, W. Germany	Acustica
AERONAUTICAL JOURNAL Royal Aeronautical Society 4 Hamilton Place London W1V OBQ, UK	Aeronaut. J.
AERONAUTICAL QUARTERLY Royal Aeronautical Society 4 Hamilton Place London W1V OBQ, UK	Aeronaut. Quart.
AIAA JOURNAL American Institute of Aeronautics and Astronautics 1290 Ave. Americas New York, NY 10019	AIAA J.
APPLIED MATHEMATICAL MODELING IPC House, 32 High Street Guildford Surrey GU1 3EW, UK	Appl. Math. Modeling
ARCHIVE FOR RATIONAL MECHANICS AND ANALYSIS Springer-Verlag New York Inc. 175 Fifth Ave. New York, NY 10010	Archive Rational Mech. Anal.
ARCHIVES OF MECHANICS (ARCHIWUM MECHANIKI STOSOWANEJ) Export and Import Enterprise Ruch UL, Wronia 23, Warsaw, Poland	Arc. Mech. Strosowanej
ATM MESSTECHNISCHE PRAXIS R. Oldenbourg Verlag GmbH Rosenheimer Str. 145 8 München 80, W. Germany	Messtech- nishe Praxis
AUTOMOBILTECHNISCHE ZEITSCHRIFT Franckh'sche Verlagshandlung Abteilung Technik 7000 Stuttgart 1, Pfizerstrasse 5-7 W. Germany	Automobil- tech. Z.
AUTOMOTIVE ENGINEER P. O. Box 24, Northgate Ave. Bury St. Edmunds Suffolk 1P32 GBW UK	Auto. Engr.
BALL BEARING JOURNAL (English Edition) SKF (U.K.) Ltd. Luton Bedfordshire LU3 1JF, UK	Ball Bearing J.
BAUINGENIEUR S Hirtzel Verlag, Postfach 347 D-700 Stuttgart 1, W. Germany	Bauingen- ieur
BROWN BOVERI REVIEW Brown Boveri and Co., Ltd. CH-5401, Baden, Switzerland	Brown Boveri Rev.
BULLETIN DE L'ACADEMIE POLONAISE DES SCIENCES, SERIES DES SCIENCES TECHNIQUES Ars Polona-Ruch 7 Krokowskie Przedmiescie, Poland	Bull. Acad. Polon. Sci., Ser. Sci. Tech.
BULLETIN OF THE FACULTY OF ENGINEERING, YOKAHOMA NATIONAL UNIVERSITY Yokahoma National University OHKA-MACHI, Minami-ku Yokahoma, Japan	Bull. Fac. Engr. Yokahoma Natl. Univ.
BULLETIN OF JAPAN SOCIETY OF MECHANICAL ENGINEERS Japan Society of Mechanical Engineers Sanshin Hokusei Bldg. H-9 Yoyogi 2-chome Shibuya-ku Tokyo 151, Japan	Bull. JSME
BULLETIN OF SEISMOLOGICAL SOCIETY OF AMERICA Bruce A. Bolt Box 826, Berkeley, CA 94705	Bull. Seismol. Soc. Amer.
CIVIL ENGINEERING (NEW YORK) ASCE Publications Office 345 E. 47th St., United Engr. Ctr. New York, NY 10017	Civ. Engr. (N.Y.)
CLOSED LOOP MTS Systems Corp. P. O. Box 24012 Minneapolis, MN 55424	Closed Loop
COMPUTERS AND STRUCTURES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Computers and Struc.
DESIGN NEWS Cahners Publishing Co., Inc. 221 Columbus Ave. Boston, MA 02116	Design News
DIESEL AND GAS TURBINE PROGRESS Diesel Engines, Inc. P. O. Box 7406 Milwaukee, WI 53213	Diesel and Gas Turbine Progress
ENGINEERING MATERIALS AND DESIGN IPC Industrial Press Ltd. 33-40 Bowling Green Lane London EC1R, UK	Engr. Matl. Des.
ENVIRONMENTAL QUARTERLY Environmental Publications, Inc. 252-46 Leeds Rd. Little Neck, NY 11362	Environ. Quart.

PUBLICATION AND ADDRESS	ABBREVIATION
EXPERIMENTAL MECHANICS Society for Experimental Stress Analysis 21 Bridge Sq., P.O. Box 277 Westport, CT 06880	Exptl. Mech.
FORSCHUNG IM INGENIEURWESEN Verein Deutscher Ingenieur, GmbH Postfach 1139, Graf-Recke Str. 84 4 Duesseldorf 1, W. Germany	Forsch. Ingenieurw.
GAS TURBINE INTERNATIONAL Gas Turbine 80 Lincoln Ave. Stamford, CT 06904	Gas Turbine Intl.
HIGH-SPEED GROUND TRANSPORTATION JOURNAL Planning Transportation Assoc. Inc. P O Box 4824, Duke Station Durham, NC 27706	High-Speed Ground Transp. J.
HYDROCARBON PROCESSING Gulf Publishing Co. Box 2608 Houston, TX 77001	Hydrocarbon Processing
IBM JOURNAL OF RESEARCH AND DEVELOPMENT International Business Machines Corp. Armonk, NY 10504	IBM J. Res. Dev.
INDUSTRIAL RESEARCH Dun-Donnelley Publishing Corp. 222 S. Riverside Plaza Chicago, IL 60606	Indus. Res.
INGENIEUR-ARCHIV Springer-Verlag New York Inc. 175 Fifth Ave. New York, NY 10010	Ing. Arch.
INSTITUTION OF MARINE ENGINEERS, TRANSACTIONS Marine Media Management Ltd. Memorial Bldg., 76 Mark Lane London EC3R 7JN, UK	Instn. Mar. Engrs., Trans.
INSTITUTION OF MECHANICAL ENGINEERS, (LONDON) PROCEEDINGS Institution of Mechanical Engineers 1 Birdcage Walk, Westminster, London SW1, UK	Instn. Mech. Engr. Proc.
INSTRUMENT SOCIETY OF AMERICA, TRANSACTION Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222	ISA Trans.
INTERNATIONAL JOURNAL OF CONTROL Taylor and Francis Ltd. 10-14 Macklin St. London WC2B 5NF, UK	Intl. J. Control
INTERNATIONAL JOURNAL OF EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS John Wiley and Sons, Ltd. 650 Third Ave. New York, NY 10016	Intl. J. Earthquake Engr. Struc. Dynam.

PUBLICATION AND ADDRESS	ABBREVIATION
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Engr. Sci.
INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mach. Tool Des. Res.
INTERNATIONAL JOURNAL OF MECHANICAL SCIENCES Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mech. Sci.
INTERNATIONAL JOURNAL OF NONLINEAR MECHANICS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Nonlinear Mech.
INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING John Wiley and Sons, Ltd. 605 Third Ave. New York, NY 10016	Intl. J. Numer. Methods Engr.
INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Solids Struc.
ISRAEL JOURNAL OF TECHNOLOGY Weizmann Science Press of Israel Box 801, Jerusalem, Israel	Israel J. Tech.
JAPAN SHIPBUILDING AND MARINE ENGINEERING Technical Information Service, Inc. 2-8 Kanda-Kagi-cho, Chiyoda-ku Tokyo, Japan	J. Shipbldg. Mar. Engr.
JOURNAL DE MÉCANIQUE Gauthier-Villars 55 Quai des Grands Augustines, Paris 6, France	J. de Mécanique
JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA American Institute of Physics 335 E. 45th St. New York, NY 10010	J. Acoust. Soc. Amer.
JOURNAL OF AIRCRAFT American Institute of Aeronautics and Astronautics, 1290 Ave. Americas, New York, NY 10019	J. Aircraft
JOURNAL OF THE AMERICAN CONCRETE INSTITUTE American Concrete Institute P. O. Box 4754, Redford Station Detroit, MI 48219	J. Amer. Concrete Inst.
JOURNAL OF THE AMERICAN HELICOPTER SOCIETY American Helicopter Soceity, Inc. 30 E. 42nd St. New York, NY 10017	J. Amer. Helicopter Soc.

PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF BALLISTICS 1339 Brandywine St. Philadelphia, PA 19123	J. Ballistics
JOURNAL OF COMPOSITE MATERIALS Technomic Publishing Co., Inc. 265 Post Road West Westport, CT 06880	J. Composite Matl.
JOURNAL OF ENGINEERING MATHEMATICS Academic Press 198 Ash Street Reading, MA 01867	J. Engr. Math.
JOURNAL OF ENVIRONMENTAL SCIENCES *Institute of Environmental Sciences* 940 E. Northwest Highway Mt. Prospect, IL 60056	J. Environ. Sci.
JOURNAL OF THE FRANKLIN INSTITUTE Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Franklin Inst.
JOURNAL OF THE INSTITUTE OF ENGINEERS, AUSTRALIA Science House, 157 Gloucter Sidney, Australia 2000	J. Inst. Engr., Australia
JOURNAL OF MECHANICAL ENGINEERING SCIENCE Institution of Mechanical Engineers 1 Birdcage Walk, Westminster London SW1 H9, UK	J. Mech. Engr. Sci.
JOURNAL OF MECHANICAL LABORATORY OF JAPAN (English Edition) The Government Mechanical Lab., Agency of Industrial Science and Technology, 4-12 Igusa Suginami-ku Tokyo, Japan	J. Mech. Lab. Japan
JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Mech. Phys. Solids
JOURNAL OF PHYSICS E. (SCIENTIFIC INSTRUMENTS) American Institute of Physics 335 E. 45th St. New York, NY 10017	J. Phys. E. (Sci. Instr.)
JOURNAL OF SHIP RESEARCH Society of Naval Architects and Marine Engineers 20th and Northhampton Sts. Easton, PA 18042	J. Ship Res.
JOURNAL OF THE SOCIETY OF ENVIRONMENTAL ENGINEERS The Moding Press Ltd. 6 Conduit St. London W1R 9TG UK	J. Soc. Environ. Engr.
JOURNAL OF SOUND AND VIBRATION Academic Press 111 Fifth Ave., New York, NY 10019	J. Sound Vib.

PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF SPACECRAFT AND ROCKETS American Institute of Aeronautics and Astronautics, 1290 Ave. Americas New York, NY 10019	J. Spacecraft and Rockets
JOURNAL OF TESTING AND EVALUATION American Society for Testing & Materials 1916 Race St. Philadelphia, PA 19103	J. Test Eval.
LUBRICATION ENGINEERING American Society of Lubrication Engineers, 838 Busse Highway Park Ridge, IL 60068	Lubric. Engr.
MACHINE DESIGN Penton Publishing Co. Penton Bldg., Cleveland, OH 44113	Mach. Des.
MASCHINENBAUTECHNIK VEB Verlag Technik Oranienburger Str. 13/14 102 Berlin, E. Germany	Maschinenbautechnik
MÉCANIQUE APPLIQUÉE Editions de l'Academie De La Republique Socialiste de Roumanie 3 Bis Str., Gutenberg Bucarest, Romania	Mécanique Appliquée
MECCANICA Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Meccanica
MECHANICAL ENGINEERING American Society of Mechanical Engineers 345 E. 47th St. New York, NY 10017	Mech. Engr.
MECHANICS RESEARCH AND COMMUNICATIONS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Res. and Comm.
MECHANISM AND MACHINE THEORY *Pergamon Press, Inc.* Maxwell House, Fairview Park Elmsford, NY 10523	Mech. and Mach. Theory
MEMOIRES OF THE FACULTY OF ENGINEERING, KYOTO UNIVERSITY Kyoto University Kyoto, Japan	Mem. Fac. Engr., Kyoto Univ.
MEMOIRES OF THE FACULTY OF ENGINEERING, NAGOYA UNIVERSITY Library, Nagoya University The Faculty of Engineering Furo-Cho, Chikusa-ku Nagoya, Japan	Mem. Fac. Engr., Nagoya Univ.
MTZ MOTORTECHNISCHE ZEITSCHRIFT Frankh'sche Verlagshandlung 7 Stuttgart 1, Pfizerstrasse 5-7 W. Germany	MTZ Motortech. Z.

PUBLICATION AND ADDRESS	ABBREVIATION
NAVAL ENGINEERS JOURNAL American Society of Naval Engineers Inc. Suite 507 Continental Bldg. 1012 14th St., N.W. Washington, D.C. 20005	Naval Engr. J.
NOISE CONTROL, VIBRATION AND INSULATION Trade and Technical Press Ltd. Crown House, Morden Surrey SM4 5EW, UK	Noise Control, Vib. and Insul.
NOISE CONTROL ENGINEERING P.O. Box 2167 Morristown, NJ 07960	Noise Control Engr.
NUCLEAR ENGINEERING AND DESIGN North Holland Publishing Co. P.O. Box 3489 Amsterdam, The Netherlands	Nucl. Engr. Des.
OIL AND GAS JOURNAL The Petroleum Publishing Co. 211 S Cheyenne Tulsa, OK 74101	Oil and Gas J.
OSAKA UNIVERSITY, TECHNICAL REPORTS Faculty of Technology Osaka University Miyakojima, Osaka, Japan	Osaka Univ., Tech. Rept.
PACKAGE ENGINEERING 5 S. Wabash Ave. Chicago, IL 60603	Package Engr.
POWER TRANSMISSION DESIGN Industrial Publishing Co. Division of Pittway Corp. 812 Huron Rd., Cleveland, OH 44113	Power Transm. Des.
PROCEEDINGS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS Publications Office, ASCE United Engineering Center, 345 E. 47th St. New York, NY 10017	
JOURNAL OF THE ENGINEERING MECHANICS DIVISION	ASCE J. Engr. Mech. Div.
JOURNAL OF THE GEOTECHNICAL ENGINEERING DIVISION	ASCE J. Geotech. Engr. Div.
JOURNAL OF THE STRUCTURAL DIVISION	ASCE J. Struc. Div.
POWER Power P. O. Box 521 Hightstown, NJ 08520	Power
PRODUCT ENGINEERING (NEW YORK) McGraw-Hill Book Co. P. O. Box 1622, New York, NY	Product Engr. (N.Y.)
ROYAL INSTITUTION OF NAVAL ARCHITECTS, TRANSACTIONS Royal Institution of Naval Architects 10 Upper Belgrave St. London SW1X 8BQ, UK	Roy. Instn. Naval Arch., Trans.
SAE PREPRINTS *Society of Automotive Engineers* Two Pennsylvania Plaza New York, NY 10001	SAE Prepr.
SHIPBUILDING AND MARINE ENGINEERING INTERNATIONAL Whitehall Technical Press, Ltd. Earl House, 27 Earl St., Maidstone Kent ME 1PE, UK	Shipbldg. Mar. Engr. Intl.
SIAM JOURNAL ON APPLIED MATHEMATICS Society for Industrial and Applied Mathematics, 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Appl. Math.
SIAM JOURNAL ON NUMERICAL ANALYSIS Society for Industrial and Applied Mathematics, 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Numer. Anal.
SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, NEW YORK, TRANSACTIONS Society of Naval Architects and Engineers, 20th and Northhampton St. Easton, PA 18042	Soc. Naval Arch. Mar. Engr., Trans.
S/V, SOUND AND VIBRATION Acoustic Publications, Inc. 27101 E. Oviat Rd. Bay Village, OH 44140	S/V, Sound Vib.
TRANSACTIONS OF THE AMERICAN SOCIETY OF LUBRICATING ENGINEERS Academic Press 111 Fifth Ave., New York, NY 10017	Trans. Amer. Soc. Lubric. Engr.
TRANSACTIONS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS United Engineering Center, 345 E. 47th St. New York, NY 10017	
JOURNAL OF APPLIED MECHANICS	J. Appl. Mech., Trans. ASME
JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT AND CONTROL	J. Dyn. Syst., Meas. and Control, Trans. ASME
JOURNAL OF ENGINEERING FOR INDUSTRY	J. Engr. Indus., Trans. ASME
JOURNAL OF ENGINEERING FOR POWER	J. Engr. Power, Trans. ASME
JOURNAL OF LUBRICATION TECHNOLOGY	J. Lubric. Tech., Trans. ASME
TRANSACTIONS OF THE INSTRUMENT SOCIETY OF AMERICA Instrument Society of America 400 Standix St. Pittsburgh, PA 15222	Trans. Instr. Soc. Amer.

PUBLICATION AND ADDRESS	ABBREVIATION
TRANSACTIONS OF THE NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS North East Coast Institution of Engineers Bolbec Hall, Newcastle Upon Tyne 1 UK	Trans. North East Coast Inst. Engr. Shipbldg.
VDI ZEITSCHRIFT Verein Duetscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Duesseldorf 1, Germany	VDI Z.
VEHICLE SYSTEMS DYNAMICS Swets and Zeitlinger N.V. 347 B Herreweg Lisse, The Netherlands	Vehicle Syst. Dyn.
VIBROTECHNIKA Kauno Polytechnikos Institutas Kaunas, Lithuania	Vibrotechnika
WEAR Elsevier Sequoia S.A. P. O. Box 851 1001 Lausanne 1, Switzerland	Wear
ZEITSCHRIFT FÜR ANGEWANDTE MATHEMATIK UND MECHANIK Akademie Verlag GmbH Liepsiger Str. 3-4 108 Berlin, Germany	Z. angew. Math. Mech.
ZEITSCHRIFT FÜR FLUGWISSENSCHAFTEN DFVLR D-3300 Braunschweig Flughafen, Postfach 3267, W. Germany	Z. Flugwiss

ANNUAL PROCEEDINGS SCANNED

PUBLICATION	ABBREVIATION
INTERNATIONAL CONGRESS ON ACOUSTICS, ANNUAL PROCEEDINGS	Intl. Cong. Acoust., Proc
INSTITUTE OF ENVIRONMENTAL SCIENCES, ANNUAL PROCEEDINGS Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	Inst. Environ. Sci., Proc.
MIDWESTERN CONFERENCE ON SOLID MECHANICS. ANNUAL PROCEEDINGS	Midw. Conf. Solid Mech., Proc.
THE SHOCK AND VIBRATION BULLETIN, UNITED STATES NAVAL RESEARCH LABORATORIES, ANNUAL PROCEEDINGS Shock and Vibration Information Ctr. Naval Research Lab., Code 8404 Washington, D.C. 20375	Shock Vib. Bull., U.S. Naval Res. Lab., Proc.
UNITED STATES CONGRESS ON APPLIED MECHANICS, ANNUAL PROCEEDINGS	U.S. Cong. Appl Mech., Proc.
WORLD CONGRESS ON APPLIED MECHANICS, ANNUAL PROCEEDINGS	World Cong. Appl. Mech., Proc.

CALENDAR

MEETING	DATE	LOCATION	CONTACT
	1977 JUNE		
Fuels and Lubricants Meeting, SAE	7-9	Tulsa, OK	SAE Hq.
Acoustical Society of America, Spring Meeting	7-10	State College, PA	J.C. Johnson, Appl. Res. Lab., Penn. State Univ., Box 30, State College, PA 16801
National Computer Conference	13-16	Dallas, TX	Ms. P. Isaacson, Univ. of Texas, Box 688, Richardson, TX 75080
Applied Mechanics Conference, ASME	14-16	New Haven, CT	ASME Hq.
Fluids Engineering Conference	15-17	New Haven, CT	ASME Hq.
4th International Conference on Fracture	19-24	Waterloo, Canada	Prof. T. Kawasaki, Sec. Gen., Int'l. Congress of Fracture, c/o ME Dept. Tohoku Univ., Sendai, Japan
Design Automation Conference	20-22	New Orleans, LA	H. Hayman, Box 639, Silver Spring, MD 20901
Symposium on Dynamic Tests on Soil & Rock, ASTM	26 Jun- 1 Jul	Denver, CO	ASTM Hq., Ms. J.B. Wheeler
	JULY		
Application of New Signature Analysis Technology Conference	24-29	Rendge, NH	Dr. Sanford S. Cole, Engrg. Founda-Foundation Conf., 345 E. 47th St., New York, NY 10017 Tele. (212) 644-7835
	AUG		
Society of Automotive Engineers 1977 West Coast Meeting	8-11	Vancouver, Canada	SAE Hq., A. L. Weldy
	SEPT		
Vibrations Conference, ASME	26-28	Chicago, IL	ASME Hq.
	OCT		
NOISE-CON 77	10-12	Hampton, VA	Conf. Secretariat, Noise Control Foundation, P.O. Box 3469, Arlington Branch, Poughkeepsie, NY 12603 Tele. (914) 462-6719
48th Shock and Vibration Symposium	18-20	Huntsville, AL	H. C. Pusey, Director, The Shock and Vibration Info. Ctr., Code 8404, Naval Res. Lab., Washington, D.C. 20375 Tele. (202) 767-3306
	NOV		
Winter Annual Meeting, ASME	27 Nov - 2 Dec	Atlanta, GA	ASME Hq.
	DEC		
Sixth Turbomachinery Symposium	6-8	Houston, TX	Dr. M.P. Boyce, Gas Turbine Labs., ME Dept., Texas A & M, College Station, TX 77843

CALENDAR

MEETING	DATE	LOCATION	CONTACT
	1977 DEC		
Acoustical Society of America, Fall Meeting	13-16	Miami Beach, FL	ASA Hq.
	1978 MAR		
Applied Mechanics Western and J.S.M.E. Conference	25-27	Honolulu, Hawaii	ASME Hq.
	APR		
Design Engineering Conference & Show, ASME	3-5	Chicago, IL	R.C. Rosaler, Rice Assoc., 400 Madison Ave., N.Y., NY 10017
Gas Turbine Conference & Products Show, ASME	9-13	London	ASME Hq.
Diesel & Gas Engine Power Conference and Exhibit	Apr 30 - May 4	San Francisco, CA	ASME Hq.
	MAY		
Inter-NOISE 78	1-3	San Francisco, CA	INCE, W.W. Lang
IX Southeastern Conference on Theoretical and Applied Mechanics (SECTAM)	4-5	Nashville, TX	Dr. R.J. Beil, SECTAM, Dept. of Engrg. Sci. & Mech., Virginia Polytechnic Inst. & State University Blacksburg, VA 24061
Offshore Technology Conference	8-11	Houston, TX	SPE, Mrs. K. Lee, Mtgs. Section, 6200 N. Central Expressway, Dallas, TX 75206
Society for Experimental Stress Analysis	14-19	Wichita, KS	SESA, B.E. Rossi

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS: American Federation of Information Processing Societies
210 Summit Ave., Montvale, N.J. 07645

AGMA: American Gear Manufacturers Association
1330 Mass. Ave., N.W.
Washington, D.C.

AIAA: American Institute of Aeronautics and Astronautics, 1290 Sixth Ave.
New York, N.Y. 10019

AIChE: American Institute of Chemical Engineers
345 E. 47th St.
New York, N.Y. 10017

AREA: American Railway Engineering Association
59 E. Van Buren St.
Chicago, Ill. 60605

AHS: American Helicopter Society
30 E. 42nd St.
New York, N.Y. 10017

ARPA: Advanced Research Projects Agency

ASA: Acoustical Society of America
335 E. 45th St.
New York, N.Y. 10017

ASCE: American Society of Civil Engineers
345 E. 45th St.
New York, N.Y. 10017

ASME: American Society of Mechanical Engineers
345 E. 47th St.
New York, N.Y. 10017

ASNT: American Society for Nondestructive Testing
914 Chicago Ave.
Evanston, Ill. 60202

ASQC: American Society for Quality Control
161 W. Wisconsin Ave.
Milwaukee, Wis. 53203

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, Pa. 19103

CCCCAM: Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada

IEEE: Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, N.Y. 10017

IES: Institute Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, Ill. 60056

IFToMM: International Federation for Theory of Machines and Mechanisms, US Council for TMM, c/o Univ. Mass., Dept. ME, Amherst, Mass. 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch,
Poughkeepsie, N.Y. 12603

ISA: Instrument Society of America
400 Stanwix St., Pittsburgh, Pa. 15222

ONR: Office of Naval Research
Code 40084, Dept. Navy, Arlington, Va. 22217

SAE: Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, Pa. 15096

SEE: Society of Environmental Engineers
6 Conduit St.
London W1R 9TG, England

SESA: Society for Experimental Stress Analysis
21 Bridge Sq.
Westport, Conn. 06880

SNAME: Society of Naval Architects and Marine Engineers, 74 Trinity Pl.
New York, N.Y. 10006

SVIC: Shock and Vibration Information Center
Naval Research Lab., Code 8404
Washington, D.C. 20375

URSI-USNC: International Union of Radio Science - US National Committee c/o MIT Lincoln Lab., Lexington, Mass. 02173